HAND BOOK

OF

CASINGHEAD GAS

By

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PREFACE

ONE of the greatest steps taken during the past few years for the conservation of natural resources has been the utilization of natural gas (using the term in its broadest sense) to produce gasoline. There are already several processes for extracting gasoline from natural gas, and the industry is being developed to a wonderful extent. With the inception of any new business comes the desire for reliable information on the part of the operator and investor.

Following our long established policy of trying to keep abreast of all developments in the gas industry so that we may be of real service to those already interested or to those who may become interested, we have been directing our resources and energies during the past year towards the collection of facts and figures together with data pertaining to the actual producing of gasoline from natural gas. We now, under the editorship of Mr. H. P. Westcott, take pleasure in presenting this Hand Book of Casinghead Gas.

No expenditure of time or money has been spared to corroborate the statements and information here presented. The author has visited a great number of gasoline plants that are in successful operation, he has had access to their reports, and has been given opportunity to prove their accuracy. While there will be future developments modifying or supplementing present theories and practices, as is natural in any new industry, at the present time we believe that we are presenting the most reliable data that is available.

Together with the author, we desire to thank personally Mr. George A. Burrell, Mr. A. N. Kerr, Mr. W. P. Donovan, Mr. P. M. Biddison, Mr. W. H. Cooper, and many others who have in a large or small way assisted in furnishing the material for this book.

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PART ONE

General

From the very beginning of the oil industry, the flambeau torch, burning casinghead gas, was found in every oil pool, and was typical of the industry. Without it an oil pool would hardly be recognized. This was really the first use that casinghead gas was put to, and it was considered a necessity. Now their numbers are restricted and it is considered a wasteful custom.

After the flambeau torch, the gas was used under boilers and for domestic purposes on the lease; then followed its use in gas engines for pumping and drilling, but it was not until 1903 that the true value of the gas became known. In that year the extraction of gasoline from casinghead gas was first accomplished. Like the oil business, the beginning was small, yet this year, 1916, but thirteen years later, the extraction of gasoline from gas has grown to enormous proportions.

For many years the gas was allowed to go to waste in the atmosphere, with no attempt to conserve or use it except as in the beginning, in flambeau torches and later for power and domestic purposes. Generally but a very small percentage of the casinghead gas produced on any one lease was used and the balance was allowed to escape in the atmosphere. It is absolutely impossible to place a monetary value on the waste of casinghead gas in years past, and while there is still great waste going on, it is fast becoming a thing of the past.

In 1915 it is estimated that there was over 30 billion cubic feet of casinghead gas used in making gasoline by the compression process. This volume of gas carried approxi-

Fig 1—RENO GASOLINE PLANT AT SISTERSVILLE, WEST VIRGINIA
One of the First Installed

mately two and one-half gallons of gasoline per thousand cubic feet. This wonderful growth exceeded all previous predictions of the government experts.

It might be said here that government experts estimate that there is as much more casinghead gas as was treated in the year 1915 that does not carry enough gasoline to make it profitable to extract the gasoline by the compression process but enough to make it profitable to utilize by the absorption process.

While the casinghead gasoline business has shown wonderful growth, the demand for gasoline has far outgrown the increased supply. In 1915 the estimated sale of natural gas in the United States was a little less than $100,000,000 and of gasoline extracted from casinghead gas approximately $8,000,000.

In 1914 the average price received per thousand cubic feet of natural gas sold in the United States was 15.9 cents. In 1915 the average amount received for the gasoline extracted from 1000 cubic feet of casinghead gas, on a basis of two and one-half gallons of gasoline extracted from 1000 cubic feet of gas, was 25 cents or approximately 10 cents greater than the average price received for 1000 cubic feet of natural gas.

In 1914 the extraction of gasoline from casinghead gas by the compression and condensation method amounted to 43,000,000* gallons of gasoline.

In addition there was used in marketing the casinghead gasoline at many plants an equivalent quantity of naptha with which casinghead gasoline was blended, thereby utilizing for the automobile, fuel, and other purposes, a very large quantity of naptha that otherwise would have been unsuited for these purposes.

*Mineral Resources of the United States U. S. Geological Survey 1914, J. D. Northrup.

Fig. 2—GLENN POOL. *Many Gasoline Plants can be seen in the Distance*

CASINGHEAD GAS

Casinghead Gas is the gas that flows from oil wells, coming out between the casing and the tubing. The volume is generally small, often amounting to but one or two thousand cubic feet in twenty-four hours, though some wells in the Cushing, Oklahoma, field flow two or three hundred thousand cubic feet of gas in twenty-four hours. Invariably the oldest wells show the richest gas. If the well is shut in at the casinghead or top of the well, it may accumulate a pressure of from twenty to sixty pounds.

With small wells, many are required to supply a sufficient amount of gas to make it profitable for the extraction of gasoline.

The gas generally comes in through the oil sand with the oil. The pumping of the oil has a tendency to increase the flow of gas from the oil sand. Likewise pumping the gas at a vacuum increases the flow of oil and increases the quantity of gasoline that the gas will pick up. Consequently pumping the gas under a vacuum which increases both the flow of gas and oil, is a valuable aid to the oil producer in the production of oil from the well.

Producing Gasoline from Casinghead Gas—Generally a gasoline plant or property consists of a number of oil leases grouped around a main compressor station in which the actual making of gasoline takes place. The gas lines from different wells on each lease run to a main line in which is placed a meter to measure the gas from that lease. The main line runs to the compressor station or plant.

There are a few plants extracting gasoline from a volume as small as five thousand cubic feet of gas per day while some of the large plants are extracting gasoline from a volume of two and three million cubic feet per day.

The amount of gas necessary to make a profitable proposition is not only dependent upon the volume of gas but also on the quality of the gas. In other words, a plant

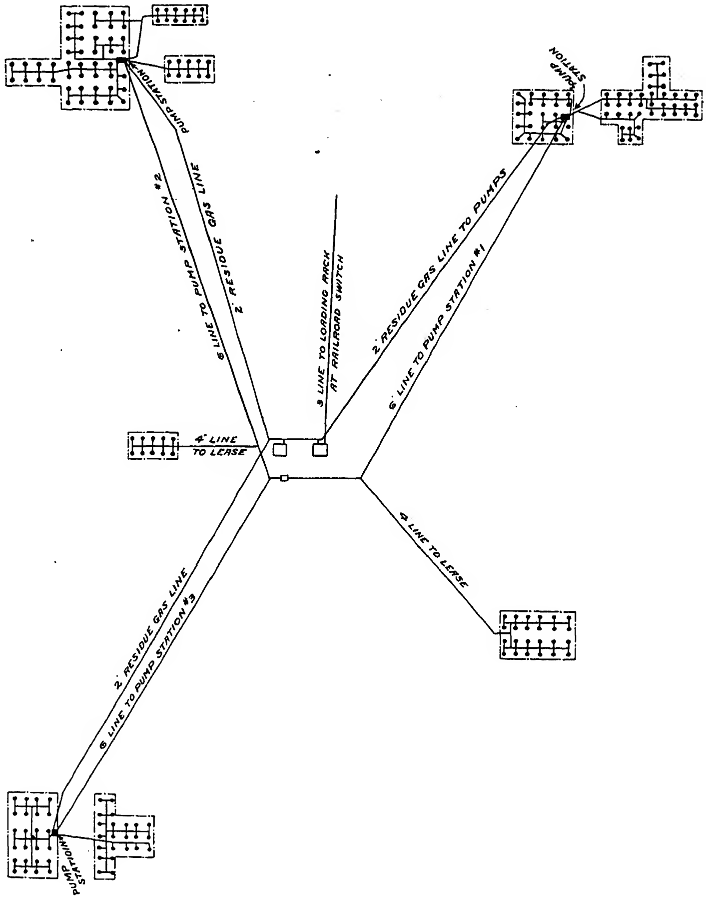


Fig. 3—GENERAL PLAN OF A GASOLINE PLANT
Showing Casinghead Gas and Residue Gas Lines to Various Groups of Leases

making six gallons of gasoline per thousand cubic feet from a volume of 100,000 cubic feet of gas per day is more profitable than a plant making but three gallons of gasoline per thousand cubic feet from a volume of 200,000 cubic feet of gas per day. The advantage is slight and arises from the fact that a smaller plant would be required for the smaller volume.

When there are scattered leases producing casinghead gas, booster stations consisting of a small compressor, are located on the separate leases to assist in forcing the gas to the main plant where the gasoline is produced.

To further assist in the production, a vacuum pump or compressor is installed in the same building with the booster compressor. The object of the vacuum pump is to pump the gas from the wells and place a vacuum on them which materially increases the flow of the gas.

Casinghead gas is generally purchased at a few cents per thousand cubic feet, figured on a four ounce basis, settlements being made monthly. The price varies according to the market price of gasoline. In some contracts the price of gas changes with the price of gasoline.

There are two processes of extracting gasoline. The one most commonly used is that by compression. The other is the absorption process, which is not only used with casinghead gas but also with natural gas, commonly called "lean gas," which carries as low as one-tenth of a gallon or less of gasoline per one thousand cubic feet. The absorption process is used with gas at high pressure as well as at low pressure.

In the compression process, the equipment consists of one or more two stage compressors, coils, accumulating tanks, electric generator and other accessories.

The casinghead gas is compressed to a pressure of from fifty to three hundred pounds and then passed through a system of coils on which cold water is constantly dripping.

This cools the gas, condensing the gasoline from it, the liquid being separated into respective accumulating tanks and the residue gas passing off to be used for power or heating purposes.

After the gasoline is collected in the accumulating tanks, it passes into blending-tanks, where it is blended with naphtha or other blending mediums to lower the gravity so as to permit of shipping without severe loss through evaporation and to make the shipping of it a safe matter.

The absorption process requires mainly a series of large size pipes or tanks capable of holding high pressure, in which are placed small pipes carrying a large number of small holes, generally 1-16 of an inch in diameter. The tanks or pipes are partially filled with an oil heavier than gasoline, from which the lighter hydrocarbons have previously been extracted, and the gas is turned into the tanks or pipes through the small perforated lines. The gas flowing from the small perforations comes in contact with the oil and intimately mixes with the oil as it passes through it. The absorption of gasoline from the gas takes place as the oil and gas come together. The oil is then run off and distilled by steam distillation in the same manner as at an oil refinery. The oil can be used over and over again. Sealing fluid or torch oil is commonly used for the absorption process.

History—While a few isolated instances are known where gasoline was condensed from high pressure natural gas, it was not until 1903 that the collection of gasoline from casinghead gas, and the sale of it, became an established business. In that year, across the Ohio River from Sistersville, West Virginia, were located several oil wells flowing casinghead gas. This gas was used under boilers often three or four miles distant. A steam jet at the wells was used to force the gas to the point of consumption.

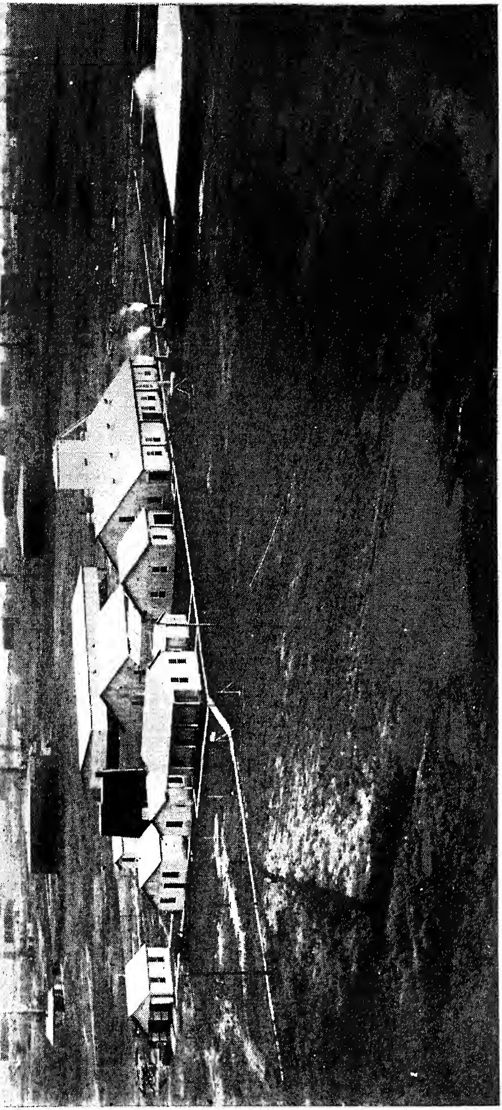


Fig. 4—GASOLINE PLANT AT KIEFER, OKLA.

It was soon discovered that the gas lines were showing considerable quantities of gasoline, especially in the low spots or sags, which led to the installation of common pipe drips along the lines. From this came the use of a system of coils placed in old boilers or tanks filled with running water. The gasoline was collected daily in wooden barrels, hauled to the river and shipped to Parkersburg, where a ready market was found.

The gasoline ran about 70 degrees Baume.

To the writer's knowledge, the first ones to establish the business of collection and sale of gasoline from casinghead gas were Sutton Bros. & Edmonds, of Sistersville, W. Va. Later on, regular vacuum pumps were installed at the casinghead gas wells for pumping gas to increase the gas supply, and compressors to assist in forcing the gas to the boilers at distant points. It was soon noted by the installation of the foregoing that the yield of gasoline was considerably increased.

In the year 1905, the first known plant especially built for extracting gasoline by the compression method was installed by William Richards, at Mayburg, Pennsylvania.

From this and the small beginning in 1903, but thirteen years ago, this industry has grown and broadened until now there are many hundred hundreds of plants scattered from the eastern oil fields to the Pacific Coast producing, in 1915, approximately eight million dollars' worth of gasoline.

MARKETED PRODUCTION OF GASOLINE FROM NATURAL GAS IN THE UNITED STATES IN 1914, BY STATES

1914

State	Number of operators	Plants		Gasoline produced			Gas used		
		Number	Daily capacity	Quantity	Value	Price per gallon	Estimated quantity	Value	Average yield in gasoline per M cubic feet
Oklahoma	35	58	74,793	17,277,555	$1,113,059	6.44	5,738,549,000	$273,940	3.01
West Virginia	65	121	34,460	9,278,108	691,899	7.45	3,005,292,000	172,396	2.58
California	17	19	32,360	7,581,309	633,517	8.36	5,129,709,000	197,066	1.48
Pennsylvania	96	119	21,456	4,611,738	359,402	7.79	1,560,064,000	125,690	2.89
Ohio	25	47	9,319	2,440,171	184,097	7.54	852,277,000	68,935	2.86
Illinois	7	14	5,300	1,164,178	100,331	8.62	462,321,000	43,017	2.52
Kansas	3	3	1,665	a299,573	23,604	7.88	146,345,000	8,862	2.03
New York	3	3							
Colorado	2	2							
Kentucky	1	...							
Total	254	386	179,353	42,652,632	3,105,909	7.28	16,894,557,000	889,906	2.43

a Includes gasoline produced in Kentucky which came from natural condensation in gas mains.

ESTIMATED GASOLINE CONTENT OF THE CRUDE PETROLEUM PRODUCED DURING 1915 *

	Field					
				Kansas-Oklahoma.		
	Appalachian	Lima-Indiana	Illinois	Kansas-Oklahoma (except Cushing and Healdton)	Cushing	Healdton
1915	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
January	17,509,800	1,779,120	13,532,400	24,911,040	86,138,640	1,219,000
February	16,909,200	1,804,320	12,902,400	22,800,960	74,923,380	126,000
March	18,738,720	1,925,280	14,338,800	21,268,800	86,569,560	218,400
April	18,406,080	1,960,560	13,448,400	23,029,440	96,040,540	567,000
May	17,297,280	1,774,080	13,440,000	25,650,240	87,805,620	588,000
June	18,081,720	1,854,720	13,213,200	23,284,800	85,344,840	924,000
July	17,897,880	1,804,320	13,322,400	26,093,760	73,086,300	1,554,000
August	17,380,440	1,688,400	13,053,600	26,013,120	63,367,920	1,457,400
September	17,186,400	1,663,200	12,692,400	25,623,360	50,226,960	2,520,000
October	16,890,720	1,688,400	12,700,800	27,115,200	43,171,380	3,351,600
November	16,456,440	1,587,600	12,163,200	24,850,560	37,864,260	5,040,000
December	17,676,120	1,632,960	12,129,600	29,272,320	36,117,900	9,765,000
Total	210,430,800	21,162,960	156,937,200	299,913,600	820,657,300	27,330,400

*From "Investigation of the Price of Gasoline," published by the Federal Trade Commission, 1916.

ESTIMATED GASOLINE CONTENT OF THE CRUDE PETROLEUM PRODUCED DURING 1915 *—Continued

	Field					
	North Texas	Northwest Louisiana	Wyoming	Gulf Coast	California	Total [1]
1915	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
January	5,434,800	12,173,600	2,914,800	1,692,180	8,082,900	175,388,280
February	5,224,800	7,912,800	2,234,400	1,911,420	7,296,450	154,046,130
March	5,896,800	9,366,000	3,057,600	1,738,800	7,945,350	171,064,110
April	5,804,400	9,962,400	1,747,200	1,578,780	7,703,950	180,248,750
May	6,804,000	10,894,800	2,074,800	1,721,160	8,071,350	176,121,330
June	6,342,000	11,499,600	3,149,200	1,728,720	7,812,000	173,234,800
July	5,678,400	12,583,200	3,074,400	2,239,020	8,125,950	165,459,630
August	5,510,400	12,852,000	3,729,600	2,162,160	8,064,000	155,279,040
September	5,166,000	12,658,800	3,183,600	2,561,580	7,706,500	141,188,800
October	5,191,000	11,205,600	3,864,000	3,814,020	8,058,750	137,051,470
November	5,056,800	10,903,200	3,292,800	3,666,340	7,626,150	128,507,350
December	4,225,200	9,954,000	3,494,400	2,879,100	7,766,850	134,913,450
Total	66,334,600	131,966,000	35,816,800	27,693,280	94,260,200	1,892,503,140

* From "Investigation of the Price of Gasoline," published by the Federal Trade Commission, 1916.

[1] To this total must be added about 63,000,000 gallons extracted from natural gas by compression; also the gasoline contents of the Colorado production and of a small amount of Illinois production are not included.

QUANTITY OF GASOLINE PRODUCED BY REFINERIES REPORTING TO THE COMMISSION, 1915*

	Refiners		
	Standard companies	Other companies	Total
1915	*Gallons*	*Gallons*	*Gallons*
January	49,500,619	27,162,918	76,663,537
February	46,053,843	24,531,091	70,584,934
March	52,079,421	28,824,590	80,904,011
April	61,039,714	30,124,059	91,163,773
May	61,048,885	32,936,152	93,985,037
June	53,117,943	35,660,139	88,778,082
July	60,074,304	35,844,836	95,919,140
August	58,545,829	34,366,594	92,912,423
September	62,337,332	35,078,242	97,415,574
October	62,275,051	36,785,348	99,060,399
November	54,406,103	36,093,920	90,500,023
December	61,242,672	36,263,545	97,506,217
Total	681,721,716	393,671,434	1,075,393,150

* From "Investigation of the Price of Gasoline," published by Federal Trade Commission.

Returns not having been received as yet from several large refineries, the statistics in the preceding table are only approximate. They indicate accurately, however, the movement of gasoline production during 1915 and correspond rather closely to the estimated gasoline content of the total crude production.

QUANTITIES OF GASOLINE PRODUCED, PURCHASED AND SOLD, AND STOCKS ON HAND THE FIRST OF THE MONTH, FOR COMPANIES REPORTING TO THE FEDERAL TRADE COMMISSION, BY MONTHS, 1915 *

	Purchases by Refiners		Production		Sales by Refiners	
	Standard	Other	Standard	Other	Standard	Other
1915	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
January	6,240,825	1,045,644	49,500,619	27,162,918	36,448,134	19,266,760
February	5,930,406	818,180	46,053,843	24,531,091	32,877,068	17,883,501
March	8,265,957	1,142,346	52,079,421	28,824,590	44,322,764	24,307,277
April	13,726,850	1,243,012	61,039,714	30,124,059	68,228,731	35,811,130
May	15,627,310	1,562,474	61,048,885	32,936,152	81,911,575	40,829,697
June	18,941,357	1,681,652	53,117,943	35,660,139	94,498,266	40,590,043
July	28,024,690	4,225,171	60,074,304	35,844,836	106,319,090	45,492,308
August	26,237,735	6,265,769	58,545,829	34,366,594	115,382,292	45,438,390
September	25,722,318	3,780,265	62,337,332	35,078,242	113,198,043	44,447,488
October	26,303,596	3,916,012	62,275,051	36,785,348	103,807,908	39,958,056
November	18,374,192	2,901,309	54,406,103	36,093,920	83,447,295	38,592,897
December	18,873,221	2,004,965	61,242,672	36,263,545	66,172,685	35,841,820
Total	212,268,457	30,586,799	681,721,716	393,671,434	946,613,851	428,459,367

* From "Investigation of the Price of Gasoline," published by Federal Trade Commission.

QUANTITIES OF GASOLINE PRODUCED, PURCHASED AND SOLD, AND STOCKS ON HAND THE FIRST OF THE MONTH, FOR COMPANIES REPORTING TO THE FEDERAL TRADE COMMISSION, BY MONTHS, 1915*—Continued.

	Stocks on hand on the 1st day of the month				Total stocks on hand (refiners and jobbers)
	Refiners		Jobbers		
	Standard	Other	Standard	Other	
1915	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
January	170,997,303	24,048,121	12,309,438	2,934,598	210,289,460
February	194,469,231	31,655,356	12,753,903	2,784,713	241,663,203
March	215,628,092	39,233,379	11,559,997	3,026,637	269,448,085
April	232,828,867	45,147,614	11,621,994	3,487,141	293,085,616
May	240,236,121	41,416,775	10,562,705	3,522,426	295,738,027
June	240,440,067	35,021,614	13,132,496	4,014,886	292,609,063
July	217,881,531	30,714,128	14,903,028	3,717,726	267,216,413
August	202,682,999	26,859,626	13,795,622	3,507,094	246,845,341
September	168,866,420	22,189,934	14,908,848	3,122,967	209,088,169
October	139,490,540	17,835,655	15,281,999	2,822,250	175,430,444
November	122,699,611	19,192,970	14,328,596	2,978,578	159,199,755
December	111,904,034	20,631,394	16,659,496	3,317,354	152,512,278

* From "Investigation of the Price of Gasoline," published by Federal Trade Commission.

EXPORTS OF GASOLINE, NAPHTHA AND BENZINE (COMBINED), BY MONTHS, 1915 *

1915	Gallons
January	13,624,708
February	23,346,701
March	22,034,941
April	24,259,214
May	25,117,025
June	28,372,830
July	24,947,975
August	33,067,432
September	21,035,160
October	18,543,754
November	27,424,510
December	22,895,570
1916	
January	17,129,972
Annual totals:	
1915	284,669,820
1914	238,671,187
1913	188,043,379
Per cent of total gasoline content of 1915 crude exported during 1915	15

* From "Investigation of the Price of Gasoline" published by Federal Trade Commission, 1916.

The foregoing statistics are taken from the monthly reports of the Bureau of Foreign and Domestic Commerce. At the end it is shown that the total exports of all volatile petroleum products during 1915 were equal to 15 per cent of the total estimated gasoline content of all the crude petroleum produced in the United States during 1915, as estimated in Table No. 2.

AVERAGE MONTHLY F. O. B. REFINERY PRICES OF GASOLINE, STANDARD COMPANIES AND OTHER COMPANIES, BY MONTHS, 1915 *

(Cents per gallon).

	Standard companies (8 refineries).	Other companies (47 refineries).	Average, all refiners (55 refineries).
1915			
January	7.82	8.38	8.26
February	7.66	8.13	8.06
March	7.63	7.76	7.74
April	7.46	7.64	7.61
May	7.42	7.59	7.57
June	7.36	7.61	7.57
July	7.47	7.79	7.68
August	7.88	8.02	8.00
September	8.93	9.14	9.11
October	9.84	10.61	10.50
November	11.09	11.65	11.57
December	12.84	13.07	13.03

* From "Investigation of the Price of Gasoline" published by Federal Trade Commission, 1916.

The average prices f. o. b. refinery are calculated by dividing the total net receipts from sales of gasoline at the refinery by the gallons of gasoline sold. The figures are subject to slight revision, but indicate the general trend.

PART TWO

Physical Properties of Casinghead Gas

VACUUM

Throughout this book the word vacuum will be used in place of the expression "minus pressure or 'vacuum.'" A perfect vacuum has never been obtained and probably never will be. The true meaning of the word vacuum is—a void, a vacuity, a space where no material substance exists.

The meaning intended and understood by the casing-head gas fraternity is that of a partial vacuum or any minus pressure below atmospheric pressure. It is in that sense that the word vacuum is used in this book.

Gasoline Gas (*By O. J. Sieplein, Ph. D.*)—"A
when exposed to the air or to any gas, gradually c
vapor. The rate at which this change takes place
as the temperature of the liquid rises. When the vapor is being formed quietly, we speak of the liquid as evaporating or vaporizing. When the temperature is sufficiently high, the vapor forms rapidly in the body of the liquid and appears as bubbles which rise through the liquid. We say the liquid is boiling, and its temperature is its boiling point. If the liquid is pure, the boiling point will remain constant as long as there is any liquid. If we are dealing with a mixture of two liquids of different boiling points the boiling will usually begin at the boiling point of the lower boiling liquid. The temperature will gradually rise as the boiling continues until, as the last portion boils away, the temperature has reached the boiling point of the higher boiling liquid. By boiling the liquid slowly, condensing the vapors and collecting the first portions of condensate separately from the later ones,

we bring about a rough separation of the two constituents of the mixture. This is the principle made use of in the separation of petroleum into its various products by distillation, also in the manufacture of the various distilled liquors.

The boiling point of a liquid varies with the pressure exerted upon the liquid. Thus, water can be made to boil at any temperature from 32 deg. fahr. to 698 deg. fahr. Inasmuch as the normal pressure of the air is fifteen pounds per square inch, and the boiling point of water at this pressure is 212 deg. fahr., we ordinarily speak of 212 deg. fahr. as the boiling point of water.

If we close a vessel partly full of water, with a safety valve set at fifteen pounds, the pressure of the steam, i. e., the pressure on the water, when boiling takes place and the valve is opened, is fifteen pounds greater than the pressure of the air, or a total of thirty pounds. The boiling point at this pressure is 249 deg. fahr. Similarly the boiling point for a gauge pressure of thirty pounds (a total pressure of 45 pounds) is 273 deg. fahr. Speaking of these facts from a mechanical engineer's standpoint, we would say the temperature of saturated steam at fifteen pounds is 249 deg. fahr. and at thirty pounds is 273 deg. fahr.

Previous to 1880, it was thought impossible to liquefy certain gases such as air and hydrogen. These were therefore known as permanent or perfect gases. Following up the work of Cailletet, Pictet, Dewar and others in the perfection of means of producing and maintaining cold, all gases have been liquefied. The last to be liquefied was helium, an inert gas first discovered in the sun and later found to be present in the air and some minerals. The boiling point of helium is the lowest known, it being 451.6 deg. fahr. below zero. The invention by Dewar of vacuum-jacketed vessels aided more than any other one thing in the development of our knowledge in the field. This invention has become of

commercial importance, its outgrowth being the vacuum-jacketed bottle such as the thermos.

It was early recognized that there is a certain definite temperature for each substance above which it cannot be liquefied by pressure. This temperature is known as the critical temperature, and the pressure needed to produce the liquid at this temperature as the critical pressure. An example will make this point clear.

The critical temperature of water is 698 deg. fahr.; its critical pressure is 2.933 pounds per square inch. This means that at a temperature below 698 deg. fahr. steam may, by application of pressure, be converted to liquid water, and that at 698 deg. fahr. 2.933 pounds are necessary. Stated otherwise, it means that steam generated at this temperature has a total pressure of 2.933 pounds or a noticeable pressure of 2.918 pounds, the excess above the atmospheric pressure of 15 pounds. At the critical temperature the liquid passes over into the gas without expansion.

The term vapor is now applied to gases below their critical temperatures—that is, to gases which by pressure alone can be converted to liquids. The term, true, perfect or permanent gas, is applied to gases above their critical temperatures.

The volume of a gas is increased by the application of heat. These facts are known to anyone who is observant. Scientific experiment has proven that these changes in volume are perfectly regular for true gases, and are independent of the nature or composition of the gas. The changes in volume for a given change in temperature or pressure are the same for all true gases. Double pressure reduces the volume of a gas to one-half the original volume; triple pressure reduces it to one-third, etc. Four hundred and sixty cubic feet of gas at 0 deg. fahr. will increase one cubic foot for each degree that the temperature is raised. It would be 470 cubic feet at 10 deg. fahr., 480 cubic feet at

20 deg. fahr., etc. An increase of pressure on a gas meets with a certain resistance, which resistance is expressed as heat, warming the gas. If the change in pressure is gradual, the heat is radiated to surrounding objects, and not noticed. If, as in commercial practice, the change in pressure is sudden, the heat does not have opportunity to radiate and the warming of the gas is considerable. Therefore the volume resulting on doubling the pressure would be more than one-half the original volume because the temperature of the compressed gas is higher than that of the original gas. This increase of temperature varies with original temperatures, original pressures, final pressures, and also with the amount of radiation. The loss of heat by radiation is dependent on the nature of the containing vessel.

Whenever a gas bubbles through or comes into contact with a liquid it takes up vapor of that liquid. The amount of vapor, as would be inferred from former statements, increases as the temperature rises and is quite independent of the nature of the gas. Inasmuch as in the resulting mixture the gas is mixed with vapor the mixture occupies more space than the original gas. Thus 1,000 cubic feet of dry air at 50 deg. fahr. will take up nine and one-third ounces by weight of water yielding 1,012 cubic feet of moist air; 1,000 cubic feet of dry air at 80 deg. fahr. will take up twenty-five ounces, by weight, of water, yielding 1,035 cubic feet of moist air.

When natural gas in the earth comes into contact with petroleum it takes up some of the petroleum as vapor. Petroleum is composed of a large number of substances, with boiling points ranging from 320 deg. fahr. to perhaps 1,000 deg. fahr. The low boiling constituents of petroleum, when separated from the others by distillation, compose the various grades of gasolines. Higher boiling portions constitute the various grades of burning oils, paraffin, etc. Inasmuch as the temperature of the gas in the earth is nearer the

boiling points of the gasoline constituents of the petroleum, these are taken up in much larger amounts than any other portions.

If the well is under vacuum the boiling points of the various portions are lowered. Thus the temperature of the natural gas is still nearer the boiling points of the gasoline portions and greater evaporation takes place. On the other hand, if the gas is present in the well under high pressure, this pressure on the petroleum raises the boiling points. The temperature of the gas is far from the boiling points of even the gasoline constituents and consequently vaporization is small. This is exactly what we find in practice. From petroleum and gas of the same character, the gas from a well under vacuum is richer in gasoline vapor than that from a well under pressure.

When we have a mixture of gases exerting a certain total pressure, each individual constituent of the mixture exerts that fraction of the total pressure. For example, air is roughly one-fifth oxygen and four-fifths nitrogen. Of the ordinary atmospheric pressure of fifteen pounds, oxyger exerting one-fifth or three pounds while the nitrogen is e ing four-fifth or twelve pounds. If we fill a cylinder o other vessel with air, we would find exactly the same ra oxygen to nitrogen in all parts of the vessel. That is, oxygen and nitrogen are each present in all parts of the vessel. Each cubic inch of the vessel would contain 0.07 grains of oxygen and 0.25 grains of nitrogen. This corresponds to one-fifth of a cubic inch of oxygen and four-fifths of a cubic inch of nitrogen, if both gases are under a pressure of fifteen pounds. From five cubic feet of air we could therefore obtain one cubic foot of oxygen and four cubic feet of nitrogen, if all these were under fifteen pounds pressure. From the law of gas volume in relation to pressure, if we transfer the one cubic foot of oxygen at fifteen pounds to a five-cubic-foot cylinder, the pressure in this

cylinder would be three pounds. This is one-fifth of fifteen pounds. Similarly the four cubic feet of nitrogen would exert twelve pounds pressure if transferred to a five-cubic-foot cylinder. Now suppose the five cubic feet of oxygen at three pounds to be added to the five cubic feet of nitrogen at twelve pounds. Suppose also that the space occupied by the mixture be restricted to five cubic feet. The pressure must necessarily be the sum of three pounds and twelve pounds, or fifteen pounds.

In order to condense vapor, pressure must be exerted upon it or it must be cooled. If we wish to condense it by pressure alone, we must exert a pressure equal to the pressure of the vapor when the liquid is boiling at the temperature of the experiment. But if the vapor is present in mixture with another gaseous substance, only a portion of the total pressure is being exerted on the vapor. If the vapor constitutes ten per cent of the mixture, the pressure on the vapor is ten per cent of the pressure on the mixture. In such a case we would need 150 pounds pressure on the mixture to have fifteen pounds on the vapor. With the pressure of fifteen pounds on the vapor, this would condense to a liquid at the temperature at which the liquid would normally boil.

Commercial cymogene is mainly butane which boils at 34 deg. fahr. That is, at 34 deg. fahr. butane vapor exerts a pressure of fifteen pounds. To condense butane vapor at 34 deg. fahr. to a liquid by the application of pressure, we would need fifteen pounds per square inch. If the butane constituted twenty per cent of a mixture, we would need a total pressure of seventy-five pounds in order to have fifteen pounds on the butane vapor. If the butane were ten per cent of the mixture, a total pressure of 150 pounds would be necessary. With five per cent of butane, a pressure of 300 pounds would be needed. From this it will be seen why one gas may produce gasoline with 75 to 100 pounds, while

another gas will need 250 to 300 pounds to produce the same quality of gasoline.

Butane is either liquid or gas as temperature and pressure conditions may demand. As a gas it weighs almost exactly twice as much as the same volume of air. As a liquid, it weighs almost exactly (a little over) five pounds per gallon. Air weighs at sea level pressure and zero fahr. temperature 86 pounds per thousand cubic feet. A thousand feet of butane would produce about thirty-four gallons of gasoline. Then when the specific gravity of a gas runs up in the neighborhood of one and a half as referred to air, we may easily suspect that more than three and one half gallons of condensate can be recovered from it."

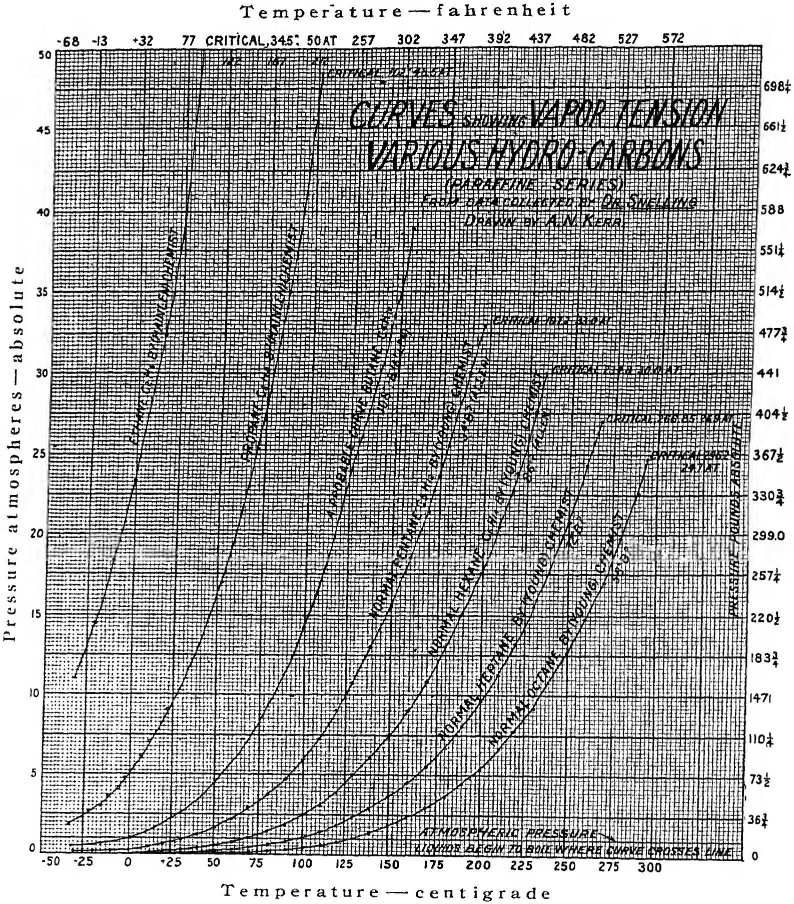

Temperature — fahrenheit
-68 -13 +32 77 CRITICAL 345° 50 AT 257 302 347 392 437 482 527 572
CURVES SHOWING VAPOR TENSION
VARIOUS HYDRO-CARBONS
(PARAFFINE SERIES)
FROM DATA COLLECTED BY DR. SNELLING
DRAWN BY A. N. KERR
ETHANE BY MAINE CHEMIST
PROPANE BY MAINE CHEMIST
A PROBABLE CURVE BUTANE
NORMAL PENTANE BY YOUNG CHEMIST
NORMAL HEXANE BY YOUNG CHEMIST
NORMAL HEPTANE BY YOUNG CHEMIST
NORMAL OCTANE BY YOUNG CHEMIST
ATMOSPHERIC PRESSURE
LIQUIDS BEGIN TO BOIL WHERE CURVE CROSSES LINE
Pressure atmospheres — absolute
PRESSURE POUNDS ABSOLUTE
50 45 40 35 30 25 20 15 10 5 0
698¼ 661½ 624¾ 588 551¼ 514½ 477¾ 441 404½ 367½ 330¾ 299.0 257¼ 220½ 183¾ 1471 110¼ 73½ 36¾ 0
-50 -25 0 +25 50 75 100 125 150 175 200 225 250 275 300
Temperature — centigrade

Fig. 5

While laboratory tests may show that it is possible to obtain from six to twelve gallons of gasoline from 1000 cubic feet of casinghead gas, it is always safer to figure from three to six gallons per 1000 cubic feet of gas.

There have been many instances where casinghead gas has, after compression and cooling, proven not to have carried enough gasoline to make it a profitable proposition. This was due to the gas having come through an oil-bearing strata, where the oil was of an asphaltum basis, and therefore very low in paraffin hydrocarbons for the gas to pick up.

All casinghead gas contains hydrocarbons of the higher orders in the paraffin group, such as propane, butane, pentane, hexane and heptane, and it is the relative percentage of these present in the gas that determines the quantity and quality of the gasoline that may be extracted from it.

The specific gravity of casinghead gas has been knc to test as high as 1.65 (air = 1.0), due to the large percentag of heavy hydrocarbons present.

Natural Gas—The principal constituent is marsh gas. The exact composition varies with the different districts.

Methane—In natural gas the chief member of the marsh gas series is methane or marsh gas itself, having the formula CH_4, and a composition of 25.03% hydrogen and 74.97% carbon by weight. The name marsh gas comes from the fact that it is frequently produced by the decay of plants in swamps and the bottom of rivers. When pure it is a colorless, odorless gas, lighter than air and having a specific gravity of .559. Its gross heating value is 1003 B. t. u. per cubic foot at 60 deg. fahr. and 29.33 inches of mercury (14.65 pounds per square inch absolute.)

Ethane—Ethane C_2H_6, the next member of the marsh gas series, is sometimes found in considerable quantities in natural gas. It greatly resembles methane in its general properties, being a better fuel and burning with a slightly

1003	Methane		CH_4	-256.5
1754	Ethane		C_2H_6	-135.4
2496	Propane		C_3H_8	- 49.0
3241	Butane	110	C_4H_{10}	+ 33.8
3995	Pentane	94	C_5H_{12}	+100.4
4712	Hexane	86	C_6H_{14}	+158.0
	Heptane	74	C_7H_{16}	+208.4
	Octane	64	C_8H_{18}	+257.0
	Nonane		C_9H_{20}	+298.3
	Decane		$C_{10}H_{22}$	+334.3
	Dodecane		$C_{12}H_{26}$	+395.7
	Hexadecane		$C_{16}H_{34}$	+532.3

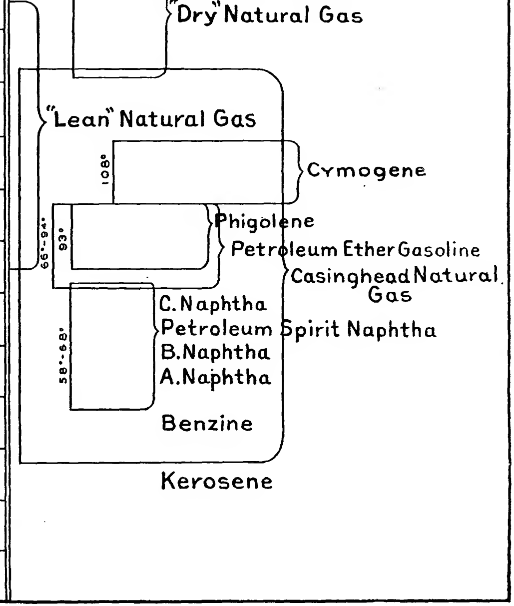


Fig. 6

inous flame, which makes it a better illuminant than thane. The heat value per cubic foot is 1754 B. t. u.

Ethane contains 79.96% of carbon and 20.04% of drogen by weight.

Oxygen O_2—This is tasteless, odorless, invisible and htly heavier than air. It exists in a free state in the nosphere and in combination in the ocean. It forms about -fifth of the former and eight-ninths of the latter.

Nitrogen N_2—This is a colorless, odorless, non-com-stible gas and is always present in large quantity in gases duced by incomplete combustion. It forms four-fifths of volume of air.

Hydrocarbons—The number of known hydrocarbons is rly two hundred. The term is applied to all compounds sisting only of hydrogen and carbon. These compounds st in gaseous, vaporous, liquid and solid states. Low tem-atures are conducive to the formation of the easily con-sed, tarry compounds, while with high temperatures, the ld of hydrogen and permanent gases is greatly increased.

British Thermal Units (B. t. u.)—The B. t. u. standard determining the quality of natural gas is universally ognized by the natural gas fraternity.

British Heat Unit, or British Thermal Unit, indicates heat necessary to raise the temperature of one pound of re water at 39 deg. fahr. through one degree.

There are two methods employed to ascertain the B. t. u. any gas. One is to use the calorimeter, and the other is to npute it from the gas analysis. In the latter case, it is essary to have the B. t. u.'s of the different gases found the analysis. These are given on page 32.

Vapor—Vapor or vapour is essentially the same as gas, t the word vapor is conventionally limited to the gaseous te of a body which is liquid or solid at ordinary tem-atures, while the term "gas" is applied to aeriform bodies ich are in that rarified state at ordinary temperatures.

Vaporize and evaporate have the same meaning—that of changing from a liquid body to a gaseous state.

Specific Gravity—It is essential to know the specific gravity to determine whether the gas from any one lease or well is of proper density to carry a sufficient amount of hydrocarbons to warrant having an analysis and test made.

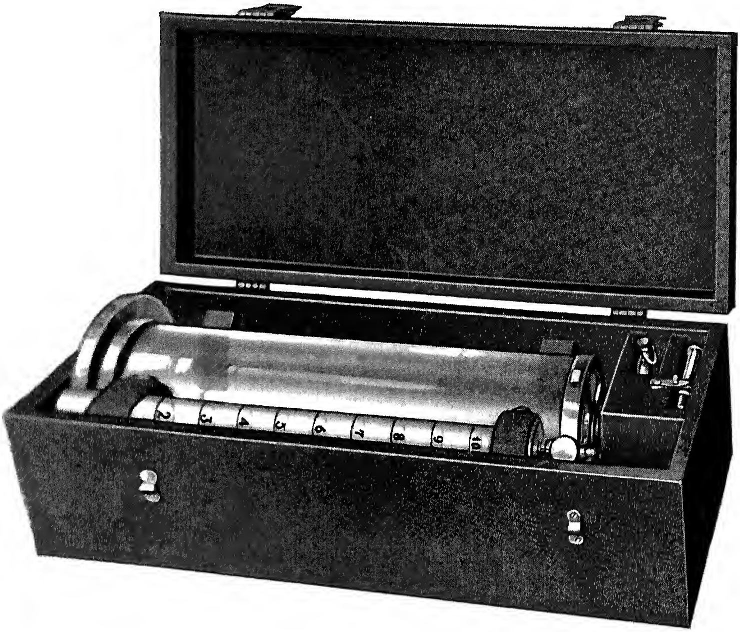


Fig. 7—SPECIFIC GRAVITY OUTFIT

By making a gravity test, the density of the gas can be accurately determined. If in testing the gravity of a certain gas it is found to be near .6, which is the gravity of natural gas, to proceed further and have an analysis made would be useless, unless one were going to use the absorption process. However, if the gravity proves to be .8 or greater, there would be little doubt of the gas carrying

enough hydrocarbons to make it profitable to make gasoline by the compression method.

The mode of operation is as follows: The glass jar is filled with water to or a little above the top graduation of the tube. The tube is then withdrawn so as to fill it with air. The cock on the standard is then closed and the tube replaced in the jar. The cock is then opened and with a stop watch the time is taken that elapses while the water passes from the lowest graduation to the top or the next to the top graduation.

The tube is then withdrawn and filled with gas and the procedure repeated the same as with air, care being taken to use the same graduation in both cases.

The specific gravity, air being one, is obtained by dividing the gas time squared by the air time squared.

Formula is—

$$\text{Specific Gravity} = \frac{G^2}{A^2} = \left(\frac{G}{A}\right)^2$$

G = Time gas requires to pass through orifice.
A = Time air requires to pass through orifice.

While boring out the hole in the tip will shorten the time for each individual test it will also greatly increase the liability of error in the final results. The longer time it takes for each test, the more accurate the results.

It is good policy not to make any gravity tests during freezing weather, as the orifice in the tip is liable to become frosted, which would cause varying and inaccurate results.

Heating Value and Specific Gravity—When it is impossible to obtain a calorimetric determination of the heating value of a particular gas, the next best procedure is to compute it from the chemical analysis of the gas, using the values shown in the following table for the heating value of the constituent gases.

Multiply the percentage of each gas present by its corresponding heating value per cubic foot, and add the products.

The specific gravity is obtained in the same manner from the specific gravities and proportions of the constituent gases shown by the analysis.

Such computed results are necessarily subject to whatever errors there may be in the analysis of the gas, and unless this has been done with great care and precision, a wide discrepancy may exist between the calculated and the actual values. The following B. t. u. values are gross or high values, and are based on one cubic foot of gas at 60 deg. fahr. and four ounce pressure, or 14.65 pounds per square inch absolute.

Kind of Gas	Symbol	Gross Heating Value B. t. u. per Cu. Ft.	Specific Gravity (Air=1)
Methane	CH_4	1003	0.5529
Ethane	C_2H_6	1754	1.0368
Ethylene	C_2H_4	1578	0.9676
Carbon monoxide	CO	322	0.9671
Hydrogen	H_2	324	0.0692
Hydrogen sulphide	H_2S	668	1.1769
Nitrogen	N_2	....	0.9701
Carbon dioxide	CO_2	....	1.5195
Helium	He	....	0.1382
Oxygen	O_2	....	1.1052

ANALYSIS OF CASINGHEAD GAS FOR GASOLINE CONTENT *

Analysis No.	Date of analysis	Location of field	Absorption heavy hydrocarbons	Carbon dioxide	Oxygen	Nitrogen	Specific gravity	Combustion ratios: Contraction	Combustion ratios: CO_2	Combustion ratios: O_2	R.	R[1].	Gallons per thousand cubic feet of gas
			Per ct.										
2500	Apr. 2, 1913	Calgary, Alberta, Can.	15	None	None	None	0.67	2.17	1.26	2.37	1.72	0.390	Dry
2430	Jan. 25, 1913	Electra, Tex	50	None	None	None	1.12	2.56	2.03	3.59	1.26	.889	3.5
2242	May 20, 1912	Oilfields, Cal	36	170	0.70	3.8	.79	2.21	1.13	2.34	1.96	.403	1.0
2747	Nov. 17, 1913	Casper, Wyo	45.1	None	None	None	1.04	2.57	1.98	4.54	1.29	.806	3.0
2748	do	do	35.5	None	None	None	.94	2.47	1.72	3.19	1.44	.653	2.0
1477	Feb. 23, 1911	Glen Pool, Okla	62.5	4.7	.80	3.0	1.16	2.62	2.15	3.77	1.22	.951	4.
2181	Jan. 2, 1912	Childers, Okla	79.3	None	None	None	1.37	2.89	2.55	4.43	1.13	.120	5.5
2065	July 17, 1911	Bremen, Ohio	25.0	None	.30	(*a*)	.67	2.09	1.10	2.19	1.98	.338	Dry
D45	Oct. 17, 1911	Cherryvale, Kans	21.2	.95	None	None	.60	2.03	1.01	2.04	2.00	.300	Dry
2533	Apr. 28, 1913	Titusville, Pa	49.2	1.50	None	None	.90	2.48	1.64	3.13	1.51	.596	2.
1632	Mar. 18, 1911	Sistersville, W. Va	45	.70	6.90	28.3	1.52	2.82	2.89	4.72	.976	1.56	Air-free
1186	Jan. 26, 1910	do	62.0	None	2.5	(*a*)	1.23	2.72	2.24	3.95	1.21	1.02	4.5
1494	Feb. 23, 1911	Kiefer, Okla	68.6	3.90	None	None	1.30	2.66	2.19	3.85	1.21	1.07	5.
2478	Mar. 1, 1913	Charleston, W. Va	22	None	None	None	.74	2.24	1.29	2.54	1.73	.427	.5
A-1-5	Feb. 10, 1910	Grove City, Pa	15	None	None	None	.63	2.04	1.02	2.06	2.00	.315	Dry

* Hill, B.—The Production of Natural Gas in 1913. *a* Not determined.

EXPERIMENTS IN LIQUEFYING CRUDE CASINGHEAD GAS

Properties of crude natural gas and of the volatilized liquid products of compression
(G. A. BURRELL, Analyst)

Analysis No.	Kind of Gas	Specific gravity *a* (air=1)	Heating value per Cu. Ft. (0 deg. cent. and 760 mm. pressure)	Composition				
				Methane	Ethane	Propane	Butane	Nitrogen
			B. t. u.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	Natural gas (Pa. and W. Va.)	0.64	1,189	83.0	16.4	....	....	0.6
2	Natural gas (Follansbee, W. Va.)	1.39	2,468	....	21.8	77.7	....	0.5
3	Residual gas after 50-pound compression product has been removed	1.35	2,364	....	34.9	64.6	....	0.5
4	Residual gas after 250-pound compression product has been removed	1.15	2,008	....	79.4	20.0	....	0.6
5	Gas from liquefied gas (400 pounds pressure, 0 deg. cent.)	1.01	1,808	3.8	95.0	....	....	1.2
6	do.	....	2,066	....	72.5	27.0	....	0.5
7	do.	1.28	2,214	....	52.1	46.9	....	1.0
8	do.	....	2,621	....	1.1	98.0	....	0.9
9	....do.	1.02	1,816	4.7	94.9	....	....	0.4
10	....do.	....	1,925	....	89.3	9.9	....	0.8
11	....do.	....	2,108	....	67.0	32.5	....	0.5
12	....do.	....	2,161	....	59.4	39.8	....	0.8
13	....do.	....	2,708	....	....	89.2	9.9	0.9
14	....do.	....	3,221	....	....	24.0	75.0	1.0

a By effusion method.
From Technical Paper No. 10—Bureau of Mines. *By Irving C. Allen and George A. Burrell—1912.*

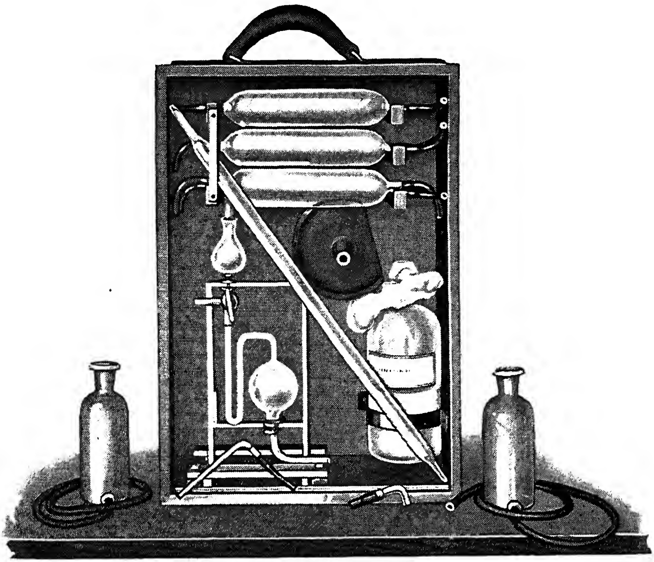


Fig. 8—ANALYZING OUTFIT FOR DETERMINING GASOLINE CONTENT IN CASINGHEAD GAS. DESIGNED BY GEORGE A. BURRELL, BUREAU OF MINES

APPARATUS FOR TESTING CASINGHEAD GAS FOR GASOLINE CONTENT

By George A. Burrell

"This apparatus consists of six gas sample tubes (A) for collecting the samples of gas; one gas measuring burette (B) for measuring the gas; one obsorption pipette (C) for absorbing the gas in oil and one bottle of oil (D).

Collection of Samples—To collect the gas sample, the sample tubes are first filled with water by opening the pinch-cocks on each tube, putting one end of the sample in the mouth, the other end in a basin of water, and filling the tube with water by sucking the latter into the tube. When the tubes are full of water the pinch-cocks are closed, thereby preventing the water from running out of the tube.

Next the end of the sample tube with the glass tube attached is placed in one of the two inch openings of the oil well casing-head (the other openings are closed) and the tube packed around with a bushing of waste or cloth or some packing that will cause a portion of the gas to pass through the tube. The pinch-cocks on the sample tube are then opened whereupon the gas will enter the sampling tube, forcing the water out. After the water has been forced out the gas should then be allowed to pass through the sampling tube for at least five minutes longer, and under such pressure that it can be easily felt or heard escaping from the tube. Next the pinch-cocks are closed. The sample of gas will then be trapped and ready for analysis.

ABSORPTION ANALYSIS TO DETERMINE GASOLINE CONTENT IN CASINGHEAD GAS

This is accomplished by shaking the natural gas with oil and noting how much of the gas is absorbed by the oil. The oil used can be Russian White oil, Claroline oil, Olive oil, Cottonseed oil, Mineral Seal oil or Rape-seed oil. They all give about the same results.

The absorption pipette C is first filled with clean potable water by pouring same in the bottle H. Enough water is poured into H so that it fills the part C up to the stop-cock K and fills the bottle H about one-fourth full. Water can be forced from H up into C by raising H and opening the stop-cock K to the air. When the water reaches K and H and is about one-fourth full the stop-cock K is closed, thereby trapping the water so it can not run out of C into H. Next oil is poured into the cup up to the mark N. This cup holds 50 cubic centimeters of oil. Then this oil is allowed to flow into the pipette C by turning the stop-cock K so the latter is in communication between M and C. The oil is allowed to flow into C so it rests on the water between the level of same and the stop-cock K. The oil is trapped in this position by closing the stop-cock K.

The gas sample is transferred to the burette B from the sample tube A by first filling the burette with water, attaching the burette to the sample tube, placing one end of the latter in a basin of water and drawing the sample into the burette. The burette B is filled by pouring the water into the level bottle P and forcing it into the burette by raising the bottle P with the pinch-cock R open. When the water has risen to R, the latter is closed thereby trapping the water in the burette. Next the sample tube is placed in the position shown with one end dipping into a basin of water. Connection is made between the sample tube and burette by means of the tube S and all of the stop-cocks are opened. The water will rise in A, will fall in B, and the gas will pass from the sample tube A to the burette B. By lowering P sufficiently as much of the gas sample can be drawn into P as is desired. It is best to transfer about 100 c. c. of gas into the burette.

The burette B is next connected to the pipette C by means of the tube T. The pinch-cock R and stop-cock K are opened and the gas forced from the burette to the pipette

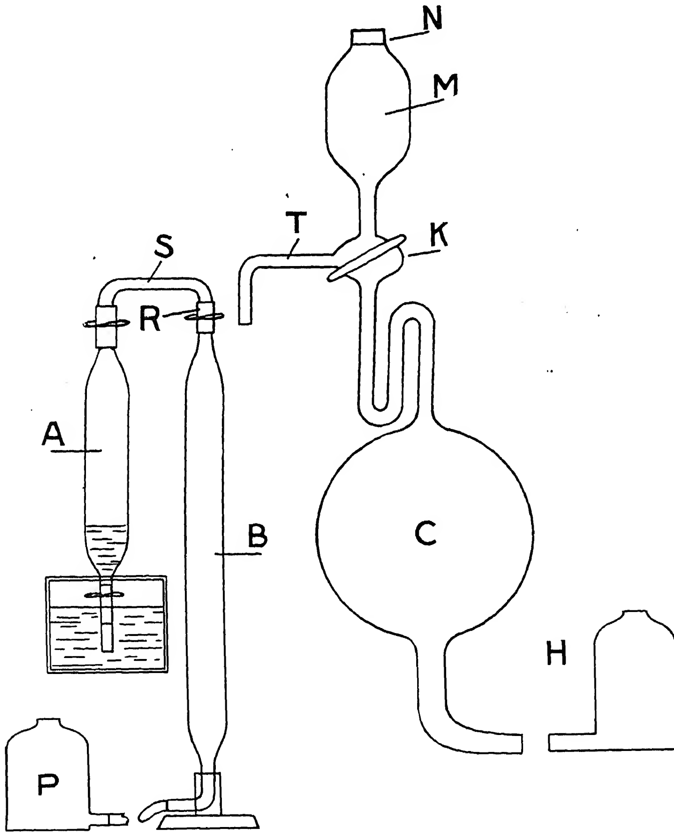


Fig. 9—SHOWING METHOD OF MAKING AN ANALYSIS OF CASINGHEAD GAS FOR GASOLINE CONTENT

by raising the bottle P. When all the gas has passed into the pipette the pinch-cock R is closed and the pipette C shaken for three minutes. This shakes the oil and gas together and causes some of the gas with its gasoline to dissolve in the oil. Next the gas is transferred back to the burette, by opening R and lowering P. The gas is then measured and the loss in volume noted. The gas is measured by closing R and holding the bottle P so the level of the water in it is on a line with the level of the water in the burette. This means that the gas in the burette is under the same pressure as the outside atmosphere. All of the gas measurements are made in this manner. If exactly 100 cubic centimeters of gas were taken for the analysis then the actual contraction in volume, i. e., the difference between the first and second burette readings gives the per cent. of natural gas absorbed, but if the amount of gas originally introduced into the burette was less than 100 c. c., then a calculation has to be made to find the true percentage. A sample calculation follows:

No. 1 analysis.

Volume of gas taken	100 c. c.
Volume of gas taken after absorption	60 c. c.
Contraction	40 c. c.
Per cent. absorbed	40 c. c.

No. 2 analysis.

Volume of gas taken	90 c. c.
Volume of gas after absorption	54 c. c.
Contraction	36 c. c.

Per cent. absorbed.... $\frac{36}{90} \times 100 = 40$

A new sample of oil must be taken for each absorption test. After one determination is finished the oil over the water in C is forced out of the pipette by raising the bottle H and opening the stop-cock K until the water rises to K. The latter is then closed.

A table follows that shows the absorption percentage corresponding to yield of gasoline in gallons per 1000 cubic feet. Yield of gasoline per 1000 cubic feet of natural gas corresponding to different absorption percentages."

Absorption Percentage	Yield of Gasoline Gallons per 1000 Cu. Ft. of Gas
25	.50
30	.75
35	1.50
40	2.00
50	2.50
60	3.50
80	5.00

PROPERTIES OF SEVEN PARAFFIN HYDROCARBONS (Bureau of Mines—Paper No. 88)

Hydrocarbon	Formula	Boiling point *b*	Specific gravity (at 0 deg. cent. and 760 mm.; air=1)	Weight of 1 litre	Heating value per cubic foot at 0 deg. cent. and 760 mm. *c*	Illuminating value	Liquefaction point	Calculated volume of gas (at 60 deg. fahr. and 30 in. barometer) pressure from 1 gallon	Theoretical volume of air necessary to burn 1 cubic ft. of gas
		deg. cent.		*Grams*	*B. t. u.*	*British candle-power*	*deg. cent.* *lb. per sq. in.*		*Cu. ft.*
Methane *d*	CH_4	—160	0.554	0.7159	1,065	5.0 *e*	—95.5 at 735 *f*; —81.8 at 807 *g*	....	9.57
Ethane *d*	C_2H_6	—93	1.049	1.3567	1,861	*h* 35.0	+35 at 664 *i*	53	16.72
Propane *d*	C_3H_8	—45	1.520	1.9660	2,654	*h* 53.9	+97 at 647 *g*	45	23.92
Butane *d*	C_4H_{10}	1.0	2.004	2.594	3,447	....	....	37	31.10
Pentane *k*	C_5H_{12}	36.4	....	....	4,250	....	....	31	38.28
Hexane *k*	C_6H_{14}	68.9	....	....	5,012	....	....	27	....
Heptane *k*	C_7H_{16}	98.4	....	....	....	....	....	....	....

b Holleman, A. F., Organic chemistry, edited by A. J. Walker, 1910, p. 41.
c Landolt and Bornstein, Physikalisch-chemische Tabellen, 3d ed., 1905, pp. 416. 425 (J. Thompson).
d Gas at ordinary temperature.
e Wright, L. T., Illuminating power of methane; Jour. Chem. Soc., vol. 47, 1885, p. 200.
f Landolt and Bornstein, Physikalisch-chemische Tabellen, 3d ed., 1905, pp. 185 (Dewar).
g Landolt and Bornstein, Physikalisch-chemische Tabellen, 3d ed., 1905, p. 185 (Olszewski).
h Frankland, P., Illuminating power of methane; Jour. Chem. Soc., vol. 47, 1885 p. 235.
i Landolt and Bornstein, Physikalisch-chemische, Tabellen, 3d ed., 1905, p. 182 (Dewar).
k Liquid at ordinary temperature.

Solution of Gas in Condensates—One of the physical changes occurring in the operation of a gasoline plant has to do with the solution of gas in the condensate, that is, when the residual gas is in contact with the condensate in the storage tank. The following experiment and calculation will serve to show how small and insignificant this change may be.

A residual gas from an operating plant was shaken with refinery naphtha. The naphtha had a specific gravity of 61 deg. B. The solution was effected at a temperature of 20 deg. cent. (68 deg. fahr.) and atmospheric pressure. The naphtha was shaken with the gas supply until no more gas would go into solution. It was found that 1 liter of the naphtha dissolved 1,760 liters of the gas; or 500 gallons of the naphtha would have dissolved 3,331.7 liters of the gas. If the assumption be made that this residual gas was ethane only, then it can be calculated that 3,331.7 liters of gaseous ethane at 16 deg. cent. (60 deg. fahr.) and 30 inches of mercury is equivalent to 2.7 gallons of liquid ethane. This quantity of liquid is so small as to seem insignificant, although as regards raising the vapor pressure of the condensate it is important.

Interpretation of Results of Tests (from Bulletin No. 88 Bureau of Mines)—"Many experiments have shown that gasoline may be obtained from natural gas having a specific gravity of 0.80 and higher (air = 1). Some inconsistencies have been noted, however, so that the authors would hesitate to recommend the installation of a plant to handle a gas that tests showed to have a specific gravity as low as 0.80 or to have an absorption percentage of 30.0 (Bureau of Mines test), although the gas might be all right for the purpose, especially if it were from wells in a field where other gases of low specific gravity were already producing gasoline. The authors do believe, however, that a gas with a tested specific

gravity as high as 0.80 and an absorption percentage as high as 40 might warrant an installation.

Natural gases differ much in composition. A so-called 'wet' gas might, for instance, contain a very large proportion of methane, with little ethane, propane, or butane, but enough of the gasoline hydrocarbons to warrant a plant installation. Such a gas when subjected to comparatively low pressures would deposit the gasoline vapors. Another gas of the same specific gravity might contain a comparatively small proportion of methane and ethane and a large proportion of propane and butane, but not enough of the gasoline hydrocarbons to warrant plant installations. Therein lies the reason why specific gravity, solubility, or combustion tests can not always be relied on.

As regards a natural gas of low specific gravity and low absorption percentage (known as a 'lean' gas), the safest recourse is to test by means of a portable outfit consisting of a gas meter, small gas engine, compressor, cooling coils, and receiver. Such an outfit can be hauled from place to place on a wagon. This method is in all cases to be recommended as having distinct advantages over laboratory tests. However, it is true that tests made with the portable outfit may be misleading unless in charge of a careful and experienced person.

RESULTS OF TESTS OF THE GRADE AND QUANTITY OF GASOLINE PRODUCED WHEN CRUDE CASINGHEAD GAS IS SUBJECTED TO DIFFERENT PRESSURES

Pressure	Temperature of cooling water	Gravity of gasoline	Yield of gasoline per 1,000 cubic feet of gas
Pounds per square inch	*deg. cent.*	*deg. Baume*	*Gallons*
110	10	....	1.8
140	10	90	3.0
190	10	94	4.5

It has been found by experiment at this plant that pressures of 140 to 150 pounds per square inch produced the most marketable gasoline. It will be observed that a pressure of 190 pounds produced more gasoline. The extra 1½ gallons, however, was of such a volatile character that it only escaped into the atmosphere upon exposure to the air; hence high pressures at this plant were unnecessary. Gasoline could be obtained by the application of pressures as little as 50 pounds per square inch, but the yield was small.

As natural gas is of different character in many different sections of the country and even in the same oil field, data obtained at one plant can not always be used as a basis for operating other plants—that is, as far as the pressures that should be used are concerned. Each operator should thoroughly test his own gas. Different pressures should be applied and the quantity and character of the gasoline noted. A reliable meter for measuring the gas becomes indispensable. If, in certain plants operating to-day, meters were installed and a series of tests conducted as above outlined, much greater efficiency of operation could be attained. Other apparatus that could be used to advantage are thermometers, graduated vessels for measuring the gasoline, hydrometers for determining the specific gravity of the gasoline, and gas-analysis apparatus, especially an apparatus for detecting air leaks in pipes through analyses of the gas for oxygen."

TABLE OF HEAT VALUES OF THE LIGHTER HYDROCARBON PRODUCTS FROM CRUDE OIL

Commercial Term	Baume	B. t. u. per lb.	B. t. u. per Standard U. S. Gallon
Gasoline...........	100	22,250	....
	95	22,050	....
	90	21,850	115,805
	85	21,650	117,343
	80	21,450	119,476
	76	21,290	120,927
	75	21,250	121,337
	73	21,170	122,150
	70	21,050	123,142
	68	20,970	123,932
	65	20,850	125,100
	64	20,810	125,484
	62	20,730	126,453
	58	20,570	127,945
Kerosene: (Water White)...	48	20,170	132,516
	46	20,090	133,397
	44	20,010	134,467
	42	19,930	135,524
	40	19,850	136,369

A gallon of 65 deg. gasoline, which weighs 5.999 pounds, will produce 22.7 cubic feet of gas; and one gallon of 70 deg. gasoline, weighing 5.85 pounds, will produce 23.1 cubic feet of gas. Temperature 60 deg. fahr.

LOW EXPLOSIVE LIMITS FOR PARAFFIN G[illegible] AND VAPORS *a* (Bureau of Mines)

The following table shows the small percentages of [illegible] and vapors occurring in natural gas that are required to [illegible] explosive mixtures with air:

Hydrocarbon	Proportion of gas air mixture constituting low explosive limit	Hydrocarbon	Proportion of gas air mixture constituting low explosive limit
	per cent		*per c[illegible]*
Methane	5.60 to 5.70	Butane	1.60 to [illegible]
Ethane	3.00 to 3.20	Pentane	1.35 to [illegible]
Propane	2.15 to 2.30		

a Burgess, M. J., and Wheeler, R. V. The lower limit of the [illegible] of mixtures of the paraffin hydrocarbons with air. Trans. Chem. [illegible] 1911, pp. 2013–2030.

According to the above table, even if a natural gas [illegible] sisted almost entirely of methane, as some natural gases [illegible] an explosion would follow an ignition of a mixture of a[illegible] natural gas containing 5.50 per cent of methane.

EXPLOSIVE MIXTURES OF COMBUSTIBLE GAS[illegible]

Combustible Gas Temperature 60 deg. to 65 deg. Fahr.	Lower Explosive Mixture	[illegible]
Air gas approximate	[illegible]	[illegible]
Hydrogen	[illegible]	[illegible]
Water gas	[illegible]	[illegible]
Acetylene	[illegible]	[illegible]
Coal gas	[illegible]	[illegible]
Ethylene	[illegible]	[illegible]
Methane	[illegible]	[illegible]
Benzene vapor	[illegible]	[illegible]
Pentane vapor	[illegible]	[illegible]
Benzoline vapor	[illegible]	[illegible]
Alcohol	[illegible]	[illegible]
Ethyl alcohol	[illegible]	[illegible]
Ether	[illegible]	[illegible]
Petrol	[illegible]	[illegible]

* Petrol Air Gas [illegible]

PHYSICAL CONSTANTS OF DIFFERENT GASES *

	SUBSTANCE	Symbol	Critical temperatures		Critical pressure	Temp. of saturated vapor at atmospheric pressure		Freezing point		Pressure at which freezing point was determined	Density of gas	Density of liquid at temperature given	Color of liquid
			deg. cent.	deg. fahr.	Atmos.	deg. cent.	deg. fahr.	deg. cent.	deg. fahr.	mm.			
1	Water.......	H_2O	365	689	200	100	212	0	32	760	.....	1 at 0·4°C.	Colorless.
2	Hyd. selenide	H_2Se	138	280·4	91	— 41	— 41·8	— 68	— 90·4	...	40	....	"
3	Ammonia ...	NH_3	130	266	115	— 33	— 27	— 77	—107	...	8·5	0·6364 at 0° C.	"
4	Propane.....	C_3H_6	97	206·6	44	— 45	— 49	Still liquid at — 151	°C.	...	20·95	....	"
5	Acetylene ...	C_2H_2	37	98·6	...	— 85	—121	— 81	—113·8	950	12·97	....	"
6	Nitrous oxide	N_2O	35	96	75	— 89	—128	—115	—175	760	21·99	....	"
7	Ethane......	C_2H_6	34	93·2	50·2	93	—135·4	Still liquid at —151	° C.	...	19 97	....	"
8	Carb.dioxide.	CO_2	31	88	75	— 80	—112	— 56	— 69	760	21·94	0·83 at 0° C.	"
9	Ozone.......	O_3	..	...	...	—106	—158·8		...	...	23·89	....	Dark blue, easily exploded.
10	Ethylene....	C_2H_4	10	50	51·7	—102	—150	—169	—272	...	13·97	....	Colorless.
11	Methane	CH_4	— 81·8	—115·2	54 9	—164	—263·4	—185·8	—302·4	80	7 98	0·415 at —164°C.	"
12	Nitric oxide .	NO	— 93 5	—135	71·2	—153·6	—254	—167	—369	138	14·98	....	"
13	Oxygen......	O_2	—118·8	—181·4	50·8	—181·4	—294·5	....	...	...	15·96	1·124 at —181·4°C.	Blue.
14	Argon.......	A	—121	—185·8	50·6	—187	—304·6	—189·6	—309·3	...	19·9	about 1.5 at —187°C.	Colorless.
15	Car.monoxide	CO	—139·5	—219·1	35·5	—190	—310	—207	—340·6	100	13·96	....	"
16	Air	..	—140	—220	39	—191·4	—312·6	...	...	...	.....	0 933 at —191·4°C.	Light blue.
17	Nitrogen....	N_2	—146	—231	35	—194·4	—318	—214	—353·2	60	14·01	0·885 at —194·4°C.	Colorless.
18	Hydrogen ...	H_2	—234	—389	20	—243	—405	...	...	...	1	....	"
19	Helium	He	...	...	...	Below —264	—443·2	...	...	...	2·02	....	

Data collected and tabulated by Walter H. Dickerson, M. E. * Liquid Air and Liquefaction of Gases by T. O. Conor Sloane, Ph. D.

VAPOR PER GALLON AND AIR REQUIRED FOR COMPLETE COMBUSTION*

	Baume	Specific gravity	Vapor cubic feet per gal. at 32 deg. fahr. 14.7 atmos.	Proportion required for perfect combustion	
				Vapor	Air
				per cent	*per cent*
Pentane	94	0.626	31.2	2.53	97.47
Hexane	81	0.663	27.7	2.17	97.83
Heptane	73	0.688	24.7	1.86	98.14
Octane	65	0.719	22.6	1.64	98.36
Nonane	59	0.741	20.8	1.47	98.53

* Petrol Air Gas by Henry O'Connor.

PART THREE

Casinghead Gas Wells

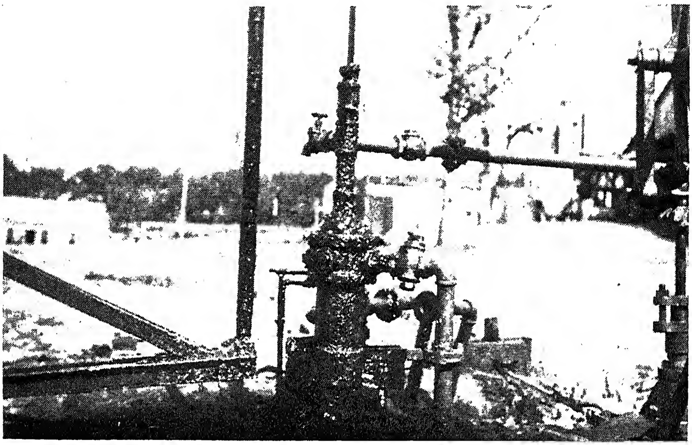


Fig. 10—A PUMPING OIL WELL SHOWING CASINGHEAD AND LEAD LINES TO CARRY THE CASINGHEAD GAS TO THE VACUUM PUMP

Throughout this book the expression casinghead gas wells refers to oil wells flowing casinghead gas. They are distinct from a natural gas well as they do not supply gas alone but a combination of gas and oil. All oil wells do not flow casinghead gas but some oil wells that have practically ceased flowing oil show a flow of casinghead gas which is worth conserving. Consequently the author considers they are in a class by themselves distinct from either oil or natural gas wells.

Preliminary to installing an expensive compression or absorption plant, with lines, etc., one should make a very careful test as to the quality and quantity of gas obtainable.

Quality of Casinghead Gas—While it is possible to send samples of casinghead gas to some laboratory or chemist for analysis and gravity test, and the practice has been quite common, the results obtained are not as satisfactory as in taking the tests on the ground at the well. The opportunity of leakage of oxygen or air into the sample bottle while enroute to the laboratory is very great and the time required enroute to the chemist entails considerable delay. Heretofore it has been the only course open to the possible investor; but with the manufacturing of a simple analyzing outfit that is portable, and with the plain instructions accompanying same, the operations in the field have become far less difficult and good reliable results are obtained.

The preliminary operations in testing casinghead gas for quality are as follows:

First—Take the specific gravity of each well under consideration and eliminate the poor well, i. e., all wells that show a gravity of less than 0.80 when intending to extract the gasoline by the compression method.

Gasoline can be extracted from casinghead gas under 0.80 by the absorption method. Some casinghead gas is, however, too low for the latter. This particularly applies to those gases that contain only methane as the paraffin hydrocarbon.

Full instructions for use of the specific gravity apparatus will be found on pages 30 and 31.

Keep a careful record of all wells showing gas of gravity of better than 0.80 or less as the case may be.

While the gravity of the gas merely shows that it may carry gasoline or in other words the gas is dense or heavy,

it must not be taken for granted that the gas carries gasoline in paying quantity for either process. The high gravity shows that the gas carries constituents other than methane but it does not show what the additional constituents are.

Second—Assuming that the gas ran high enough in gravity to warrant further investigation—make an analysis for gasoline content with some such portable analyzing outfit as shown in figure number 8, on page 35.

Full instructions for use of this instrument are found on pages 36–40.

If by this analysis the gas shows enough gasoline to warrant considering, it is far more conclusive than if merely the specific gravity of the gas is known, but even this is not sufficiently conclusive to warrant the investment of a large amount of money in a plant.

Third or Final Step—That is to prove the quality of the gas in a practical experiment by use of a portable testing outfit, which is nothing more than a minature gasoline plant built on a wagon and drawn by a team of horses from well to well.

The portable testing outfit consists of a 6 h. p. gasoline engine, a small compressor, a 300 cu. ft. per hour gas meter, 30 or more feet of cooling coils made of 1 inch pipe immersed in a tank of water, and a small storage tank. To the latter should be attached a relief valve which can be set to operate at the pressure desired. A trap should be installed between the compressor and the cooling coils to catch oil that is sometimes brought from the well with the gas. A glass gauge should be connected to the storage tank to indicate the volume of gasoline obtained.

Some companies have their portable testing outfit installed on an automobile truck in which case power for operating the compressor is obtained by jacking up one of the rear wheels of the truck, connecting the compressor by a belt to a special drum on the wheel. This outfit is not

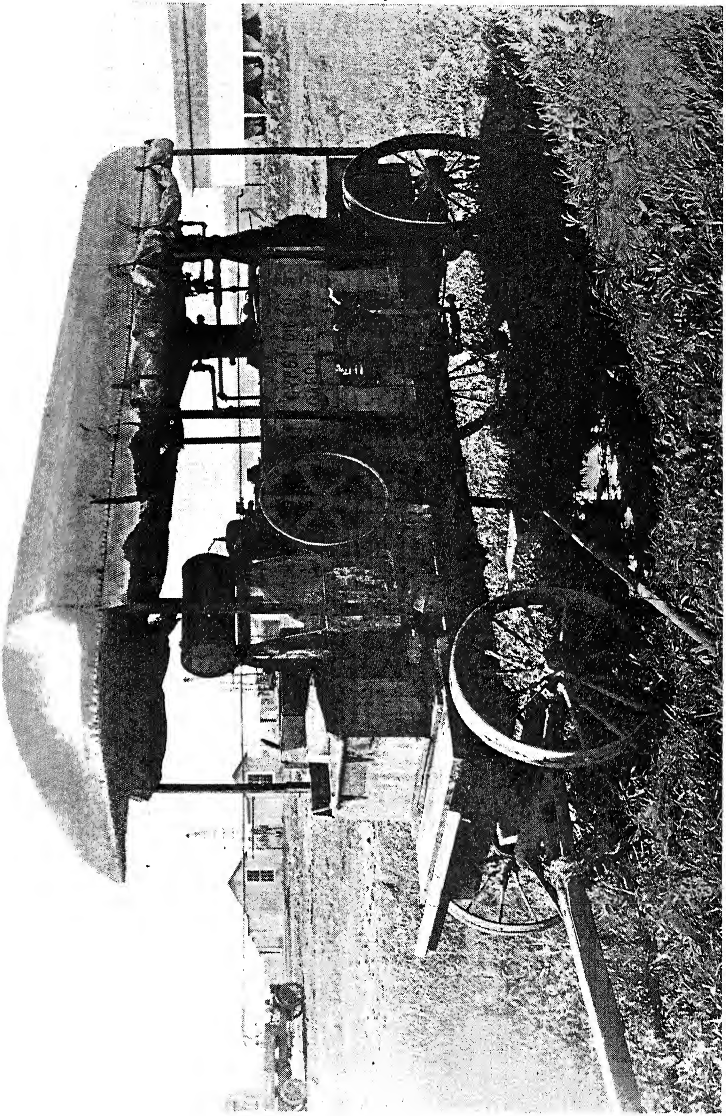


Fig. 11—PORTABLE COMPRESSION PLANT FOR TESTING CASINGHEAD GAS FOR GASOLINE CONTENT

so cumbersome and is more quickly transported from one well to another.

There are two reasons for first testing with the specific gravity outfit, one—the gravity is necessary in obtaining the volume or capacity of the well and the other — that the poor wells can quickly be determined and eliminated from further consideration.

The two outfits—specific gravity and analyzing outfits—are easily carried from well to well without any great inconvenience.

In conducting tests of casinghead gas, the plant should first be run long enough to expel all air from the compressor and lines. The meter and pressure gauges must be in good order. The cooling coils should dip enough to readily drain the gasoline into the storage tank. The efficiency of the cooling coils can be ascertained fairly well by measuring the temperature at different places in the water of the tank. At the point where the coils enter the water it will be hot enough to warm the water appreciably, but if the tank is large and a sufficient length of pipe for cooling purposes is installed the warming of the water is only local.

The pressure of the gas passing through the meter must be taken in order to ascertain the actual volume of gas treated. (For multiplier tables see page 117.)

It can hardly be said necessary to make a compressor test on the gas from every well in a group of wells on one lease or adjoining leases but it is essential to do so on at least four or five wells in twelve. The specific gravity test on each well will show any variation in density of the gas and is very essential in determining the capacity of the wells.

After the quality of the gas is fully and carefully determined then the only remaining question is as to the quantity of gas a well or group of wells will supply.

Capacity of Casinghead Gas Wells—On account of the small size of most casinghead gas wells, the old method of testing the flow by using a Pitot Tube is not practical. The orifice well tester for this character of work is considered very accurate and reliable.

To use the orifice well tester the specific gravity of the gas must be taken. This is fully described on pages 30–31.

To test a well, close all openings but one or if the well is shut in at the casinghead, blow off the well before inserting the orifice well tester. Allow the well to blow into the atmosphere for half an hour or until there is no appreciable decrease in the volume of the gas flowing from it. Screw in the orifice well tester, which carries a two-inch thread, and allow the gas to flow into the atmosphere through the proper size orifice.

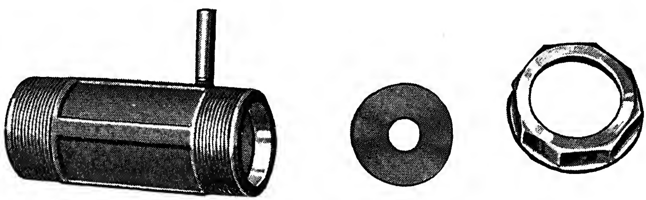


Fig. 12—ORIFICE WELL TESTER

Connect a syphon gauge to the nipple on the side of the orifice well tester, using a short piece of common three eighths inch rubber hose. The syphon gauge should be filled with water up to the zero mark on the scale. If the well appears to be large use the large sized orifice. To correctly determine the proper size orifice it is necessary to read the gauge and note the height of the water in the glass. Read both sides of the scale and add them together. In other words measure the difference between the two water levels which is the true pressure in inches of water. By referring to tables

that accompany each instrument or as found on pages 56-62 the flow of a well for a twenty-four hour period will be found under the proper gravity and opposite the pressure.

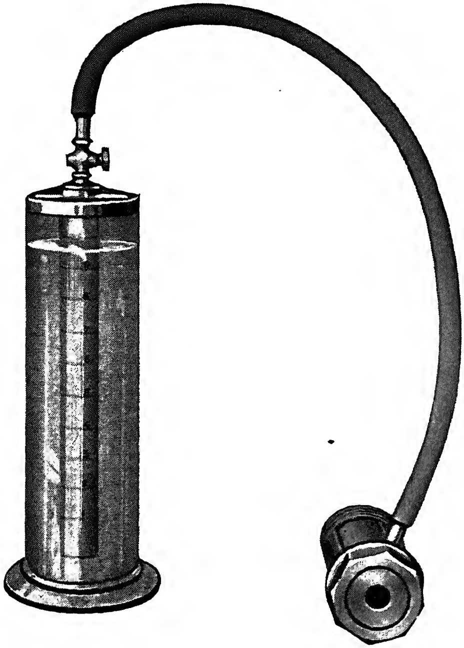


Fig. 13 SHOWS METHOD OF TAKING PRESSURE ON THE ORIFICE WELL TESTER, USING THE SPECIFIC GRAVITY TUBE IN PLACE OF A SYPHON GAUGE

The specific gravity tube can be used to take the water pressure of the gas flowing through the orifice in place of the syphon gauge. In this case measure the difference between the two levels of the water.

Use as large an orifice as possible so as not to permit the gas to create a back pressure in the well. To form a back pressure on the well will decrease the flow of the gas.

CAPACITIES, IN CUBIC FEET, PER TWENTY FOUR HOURS, OF A THREE EIGHTH INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, ONE EIGHTH INCH.

USED IN TESTING SMALL NATURAL AND CASINGHEAD GAS WELLS.

Specific Gravities—.6 to 1.7.

Temperature—60 deg. fahr. Atmospheric Pressure—14.4.

Press. in. of Water	.6	.65	.7	.75	.8	.85	.9	.95	1.
.5	2270	2180	2100	2030	1970	1910	1850	1810	1760
1	3460	3320	3200	3090	3000	2910	2820	2750	2680
1.5	4310	4140	3990	3860	3730	3620	3520	3420	3339
2	4830	4640	4470	4320	4180	4060	3940	3840	3740
2.5	5400	5190	5000	4830	4680	4540	4410	4290	4186
3	5770	5550	5350	5170	5000	4850	4720	4590	4474
3.5	6290	6050	5830	5630	5450	5290	5140	5000	4875
4	6650	6390	6160	5950	5760	5590	5430	5280	5152
4.5	7210	6930	6680	6450	6240	6060	5890	5730	5585
5	7680	7380	7110	6870	6650	6450	6270	6100	5946
5.5	8100	7790	7500	7250	7020	6810	6620	6440	6278
6	8290	7970	7680	7420	7180	6970	6770	6590	6423

Press. in. of Water	1.05	1.10	1.15	1.20	1.30	1.40	1.50	1.60	1.70
.5	1720	1680	1640	1610	1540	1490	1440	1390	1350
1	2620	2550	2500	2450	2350	2260	2190	2120	2050
1.5	3260	3180	3110	3050	2930	2820	2730	2640	2560
2	3650	3560	3490	3410	3280	3160	3050	2960	2870
2.5	4080	3990	3900	3820	3670	3540	3420	3310	3210
3	4370	4260	4170	4080	3920	3780	3650	3540	3430
3.5	4760	4650	4550	4450	4270	4120	3980	3850	3740
4	5030	4910	4800	4700	4520	4350	4210	4070	3950
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CAPACITIES, IN CUBIC FEET, PER TWENTY FOUR HOURS, OF A ONE HALF INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, ONE EIGHTH INCH.

USED IN TESTING SMALL NATURAL AND CASINGHEAD GAS WELLS.

Specific Gravities—.6 to 1.7.

Temperature—60 deg. fahr. Atmospheric Pressure—14.4.

Press. in. of Water	.6	.65	.7	.75	.8	.85	.9	.95	1.
.5	4490	4320	4160	4020	3890	3770	3670	3570	3480
1	6260	6010	5790	5600	5440	5260	5110	4970	4850
1.5	7900	7590	7310	7070	6840	6640	6450	6280	6120
2	9140	8780	8460	8170	7910	7680	7460	7260	7080
2.5	10220	9820	9470	9140	8850	8590	8350	8120	7920
3	11150	10720	10330	9980	9660	9370	9110	8860	8640
3.5	12020	11550	11130	10750	10410	10100	9810	9550	9310
4	12800	12290	11850	11440	11080	10750	10450	10170	9910
4.5	13480	12950	12480	12050	11670	11320	11000	10710	10440
5	14130	13570	13080	12640	12230	11870	11530	11230	10940
5.5	14690	14110	13600	13130	12720	12340	11990	11670	11380
6	15210	14620	14080	13610	13170	12780	12420	12090	11780

Press. in. of Water	1.05	1.10	1.15	1.20	1.30	1.40	1.50	1.60	1.70
.5	3400	3320	3250	3180	3050	2940	2840	2750	2670
1	4730	4620	4520	4420	4250	4100	3960	3830	3720
1.5	5970	5830	5710	5590	5370	5170	5000	4840	4690
2	6910	6750	6600	6460	6210	5980	5780	5600	5430
2.5	7730	7550	7380	7230	6950	6690	6470	6260	6070
3	8430	8240	8060	7890	7580	7300	7050	6830	6630
3.5	9090	8880	8680	8500	8170	7870	7600	7361	7140
4	9670	9450	9240	9050	8690	8380	8090	7840	7600
4.5	10190	9950	9730	9530	9160	8820	8520	8250	8010
5	10680	10430	10200	9990	9600	9250	8930	8650	8390
5.5	11100	10850	10610	10380	9980	9610	9290	8990	8720
6	11500	11230	10990	10760	10330	9960	9620	9310	9040

CAPACITIES, IN CUBIC FEET, PER TWENTY FOUR HOURS, OF A THREE QUARTER INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, ONE EIGHTH INCH.

USED IN TESTING SMALL NATURAL AND CASINGHEAD GAS WELLS.

Specific Gravities—.6 to 1.7.

Temperature—60 deg. fahr. Atmospheric Pressure—14.4.

Press. in. of Water	.6	.65	.7	.75	.8	.85	.9	.95	1.
.5	10560	10150	9780	9450	9150	8880	8630	8400	8180
1.	14530	13960	13450	13000	12580	12210	11860	11550	11260
1.5	17720	17030	16410	15850	15350	14890	14470	14080	13730
2.	20390	19590	18870	18230	17650	17130	16650	16200	15790
2.5	22740	21850	21050	20340	19700	19110	18570	18070	17620
3.	24880	23900	23030	22250	21550	20900	20310	19770	19270
3.5	26990	25930	24980	24140	23370	22670	22030	21450	20900
4.	28970	27830	26820	25910	25090	24340	23650	23020	22440
4.5	30800	29590	28510	27550	26670	25870	25150	24470	23860
5.	32500	31230	30090	29070	28150	27210	26540	25830	25180
5.5	34080	32740	31530	30480	29510	28630	27830	27080	26400
6	35630	34230	32990	31870	30860	29940	29090	28320	27600

Press. in. of Water	1.05	1.10	1.15	1.20	1.30	1.40	1.50	1.60	1.70
.5	7990	7800	7630	7470	7170	6920	6680	6470	6280
1.	10980	10730	10500	10280	9870	9510	9190	8900	8630
1.5	13400	13090	12800	12530	12040	11600	11210	10850	10530
2.	15410	15060	14730	14420	13850	13350	12890	12480	12110
2.5	17190	16800	16430	16080	15450	14890	14380	13930	13510
3.	18810	18380	17970	17590	16900	16290	15730	15230	14780
3.5	20400	19930	19490	19080	18330	17670	17070	16530	16030
4.	21900	21400	20920	20480	19680	18960	18320	17740	17210
4.5	23280	22750	22250	21770	20920	20160	19480	18860	18300
5.	24570	24000	23580	22980	22080	21280	20550	19900	19310
5.5	25760	25170	24620	24100	23150	22310	21550	20870	20250
6.	26930	26310	25740	25200	24200	23330	22530	21820	21170

CAPACITIES, IN CUBIC FEET, PER TWENTY FOUR HOURS, OF A ONE INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, ONE EIGHTH INCH.

USED IN TESTING SMALL NATURAL AND CASINGHEAD GAS WELLS.

Specific Gravities—.6 to 1.7.

Temperature—60 deg. fahr. Atmospheric Pressure—14.4.

Pressure in. of Water	.6	.65	.7	.75	.8	.85
1	26,440	25,440	24,500	23,660	22,920	22,220
2	37,510	36,040	34,750	33,600	32,520	31,530
3	46,440	44,640	43,000	41,540	40,240	39,020
4	52,630	50,590	48,740	47,060	45,600	44,200
5	57,880	55,630	53,610	51,790	50,160	48,640
6	63,140	60,720	58,480	56,490	54,720	53,060
7	68,110	65,470	63,090	60,910	59,040	57,210
8	73,050	70,220	67,680	65,350	63,310	61,390
9	77,680	74,680	72,000	69,500	67,340	65,280
10	82,340	79,150	76,270	73,650	71,370	69,190
11	86,680	83,320	80,300	77,540	75,120	72,840
12	90,720	87,190	84,000	81,140	78,600	76,220
Mercury						
.5	67,200	64,600	62,300	60,100	58,200	56,500
1	95,200	91,500	88,200	85,100	82,500	80,000
1.5	116,600	112,000	108,000	104,300	101,000	97,900
2	134,600	129,400	124,700	120,400	116,700	113,100
2.5	145,600	139,900	134,900	130,200	126,200	122,400
3	164,900	158,500	152,700	147,500	142,900	138,600
3.5	178,200	171,300	165,100	159,400	154,500	149,800
4	190,400	183,000	176,400	170,300	165,000	160,000
5	212,900	204,600	197,200	190,400	184,500	178,900
6	233,200	224,100	216,000	208,600	202,100	195,900
7	251,900	242,100	233,400	225,300	218,300	211,700
8	269,400	258,900	249,500	240,900	233,400	226,400
9	285,700	274,600	264,700	255,600	247,600	240,100
10	301,200	289,500	279,000	269,400	261,000	253,100
11	315,800	303,600	292,500	282,500	273,700	265,400
12	328,400	315,700	304,200	293,800	284,600	276,000

CAPACITIES, IN CUBIC FEET, PER TWENTY FOUR HOURS, OF ONE INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, ONE EIGHTH INCH.

USED IN TESTING SMALL NATURAL AND CASINHGEAD GAS WELLS.

Specific Gravities—.6 to 1.7.

Temperature—60 deg. fahr. Atmospheric Pressure—14.4.

Pressure in. of Water	.9	.95	1.	1.05	1.1	1.15
1	21,600	21,020	20,520	20,010	19,560	19,120
2	30,640	29,800	29,080	28,360	27,720	27,120
3	37,940	36,880	36,000	35,130	34,320	33,550
4	42,980	41,800	40,800	39,790	38,880	38,040
5	47,280	45,980	44,880	43,770	42,760	41,830
6	51,600	50,180	48,960	47,760	46,650	45,640
7	55,630	54,120	52,800	51,500	50,320	49,220
8	59,680	58,050	56,640	55,240	54,000	52,800
9	63,480	61,720	60,240	58,800	57,430	56,160
10	67,270	65,420	63,840	62,280	60,860	59,520
11	70,800	68,880	67,200	65,560	64,080	62,660
12	74,110	72,000	70,320	68,610	67,030	65,560
Mercury						
.5	54,900	53,400	52,100	50,800	49,600	48,600
1	77,800	75,600	73,800	72,800	70,300	68,800
1.5	95,300	92,600	90,400	88,200	86,200	84,300
2	110,000	107,000	104,400	101,800	99,500	97,300
2.5	118,900	115,700	112,900	110,100	107,600	105,300
3	134,700	131,000	127,800	124,700	121,800	119,200
3.5	145,600	141,600	138,200	134,800	131,700	128,800
4	155,600	151,300	147,600	144,000	140,700	137,600
5	174,000	169,200	165,000	161,000	157,300	153,900
6	190,500	185,300	180,800	176,400	172,300	168,600
7	205,800	200,200	195,300	190,600	186,200	182,100
8	220,100	214,000	208,800	203,700	199,100	194,700
9	233,500	227,000	221,500	216,100	211,200	206,500
10	246,100	239,300	233,500	227,800	222,600	217,700
11	258,000	250,900	244,800	238,900	233,400	228,300
12	268,400	261,000	254,600	248,400	242,700	237,400

CAPACITIES, IN CUBIC FEET, PER TWENTY FOUR HOURS, OF A ONE INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, ONE EIGHTH INCH.

USED IN TESTING SMALL NATURAL AND CASINGHEAD GAS WELLS.

Specific Gravities—.6 to 1.7.

Temperature—60 deg. fahr. Atmospheric Pressure—14.4.

Pressure in. of Water	1.2	1.3	1.4	1.5	1.6	1.7
1	18,720	18,000	17,320	16,750	16,200	15,720
2	26,540	25,480	24,570	23,760	22,990	22,290
3	32,850	31,560	30,400	29,370	28,440	27,600
4	37,220	35,760	34,460	33,310	32,230	31,270
5	40,940	39,360	37,920	36,620	35,470	34,410
6	44,680	42,960	41,370	39,960	38,680	37,530
7	48,190	46,320	44,610	43,100	41,730	40,480
8	51,690	49,680	47,850	46,220	44,760	43,410
9	54,960	52,800	50,880	49,170	47,610	46,200
10	58,240	55,960	53,920	52,100	50,440	48,960
11	61,320	58,920	56,780	54,860	53,110	51,520
12	64,170	61,680	59,400	57,400	55,580	53,920
Mercury						
.5	47,500	45,700	44,000	42,500	41,100	39,900
1	67,300	64,700	62,300	60,200	58,300	56,600
1.5	82,500	79,200	76,300	73,800	71,400	69,300
2	95,300	91,500	88,200	85,200	82,500	80,000
2.5	103,000	99,000	95,400	92,200	89,200	86,500
3	116,600	112,000	108,000	104,300	101,000	98,000
3.5	126,100	121,200	116,700	112,800	109,200	105,900
4	134,700	129,400	124,700	120,500	116,600	113,200
5	150,600	144,700	139,400	134,700	130,400	126,500
6	165,000	158,500	152,700	147,600	142,900	138,600
7	178,200	171,200	165,000	159,400	154,300	149,700
8	190,600	183,100	176,400	170,500	165,000	160,100
9	202,100	194,200	187,100	180,800	175,000	169,800
10	213,100	204,700	197,300	190,600	184,500	179,000
11	223,400	214,700	206,800	199,900	193,500	187,700
12	232,400	223,300	215,100	207,900	201,200	195,200

CAPACITIES, IN CUBIC FEET, PER TWENTY FOUR HOURS, OF A ONE AND ONE QUARTER INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, ONE EIGHTH INCH.

USED IN TESTING SMALL NATURAL AND CASINGHEAD GAS WELLS.

Specific Gravities—.6 to 1.7.

Temperature—60 deg. fahr. Atmospheric Pressure—14.4.

Press. in. of Water	.6	.65	.7	.75	.8	.85	.9	.95	1.
.5	32780	31490	30350	29320	28390	27540	26760	26050	25390
1.0	46260	44440	42830	41380	40060	38860	37770	36760	35830
1.5	56600	54380	52410	50630	49020	47560	46210	44980	43850
2.	64840	62300	60040	58000	56160	54480	52940	51530	50230
2.5	72400	69570	67040	64760	62710	60830	59120	57540	56090
3.	77980	74920	72200	69750	67540	65520	63670	61970	60410
3.5	84490	81180	78220	75570	73170	70980	68980	67140	65450
4.	91400	87810	84620	81750	79150	76790	74620	72630	70800
4.5	97810	93980	90560	87490	84710	82180	79860	77730	75770
5	103260	99210	95610	92370	89430	86760	84310	82060	80000
5.5	107230	103020	99280	95910	92870	90090	87550	85210	83060

Press. in. of Water	1.05	1.10	1.15	1.20	1.30	1.40	1.50	1.60	1.70
.5	24779	24210	23680	23180	22270	21458	20730	20070	19470
1.	34968	34160	33410	32710	31420	30280	29250	28320	27480
1.5	42790	41810	40890	40030	38460	37060	35800	34670	33630
2.	49020	47890	46840	45850	44050	42450	41010	39710	38520
2.5	54735	53480	52300	51200	49190	47400	45800	44340	43020
3.	58950	57600	56330	55150	52980	51050	49320	47760	46330
3.5	63870	62400	61030	59750	57400	55310	53440	51740	50200
4.	69090	67500	66020	64630	62090	59840	57810	55970	54300
4.5	73940	72240	70650	69170	66450	64040	61860	59900	58110
5.	78070	76280	74600	73030	70160	67610	65320	63240	61360
5.5	81060	79194	77450	75820	72850	70200	67820	65660	63700

SIZES OF CASING

Nominal Inside Diameter Inches	Outside Diameter Inches	Nominal Weight per Foot Pounds	Number of Threads per Inch	Outside Diameter of Couplings Inches
2	2¼	2.16	14	2.687
2¼	2½	2.75	14	2.875
2½	2¾	3.04	14	3.187
2¾	3	3.33	14	3.500
3	3¼	3.96	14	3.781
3¼	3½	4.28	14	4.000
3½	3¾	4.60	14	4.250
3¾	4	5.47	14	4.625
4	4¼	5.85	14	4.687
4¼	4½	6.00	14	4.937
4¼	4½	9.00	14	4.937
4½	4¾	6.55	14	5.218
4½	4¾	9.00	14	5.218
4¾	5	7.58	14	5.562
5	5¼	8.00	14	5.781
5	5¼	10.00	14	5.781
5	5¼	13.00	11½	5.781
5	5¼	17.00	11½	5.781
5 3/16	5½	8.40	14	6.062
5 3/16	5½	13.00	11½	6.062
5⅝	6	10.16	14	6.062
5⅝	6	12.00	11½	6.625
5⅝	6	14.00	11½	6.625
5⅝	6	17.00	11½	6.625
6¼	6⅝	11.50	14	7.125
6¼	6⅝	13.00	11½	7.125
6¼	6⅝	17.00	11½	7.125
6⅝	7	12.45	14	7.687
6⅝	7	17.00	10	7.687
7¼	7⅝	13.50	14	8.220
7⅝	8	15.00	11½	8.625
7⅝	8	20.00	11½	8.625
8¼	8⅝	16.00	11½	9.312
8¼	8⅝	20.00	11½	9.312
8¼	8⅝	24.00	8	9.312
8⅝	9	17.50	11½	9.750
9⅝	10	21.00	11½	10.812
10⅝	11	23.00	11½	......
11⅝	12	25.15	11½	......
12½	13	35.75	11½	......
13½	14	42.02	11½	......
14½	15	47.66	11½	......
15½	16	51.47	11½	......

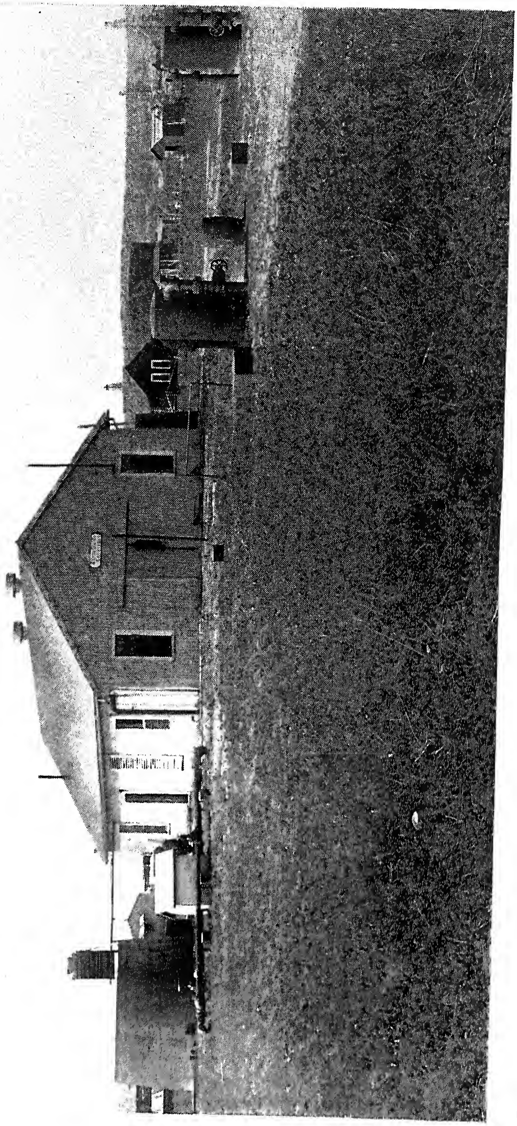


Fig. 14—BOOSTER STATION. BOTH THE VACUUM PUMP AND BOOSTER COMPRESSOR ARE INSTALLED IN THIS STATION

Booster Station—A booster station generally refers to a building near a group of casinghead gas wells in which is installed a vacuum pump and a booster or compressor. The power used is generally a gas engine for each compressor.

The vacuum pump is built with large size cylinders and is run at low speed. It is connected directly on gas lines from the casinghead gas wells.

The object in use of same is to pump or create a vacuum on the lines and wells and to deliver a large volume of gas at approximately atmospheric pressure to the booster or compressor adjoining it.

The booster or compressor receives the gas from the vacuum pump at about atmospheric pressure and raises the pressure from 25 to 40 lb. to overcome the friction in the pipe line between the booster station and the main plant.

Large tanks with baffle plates on the interior are installed on the discharge side of the vacuum pump and the booster or compressor. Considerable gasoline of low gravity is collected in same. This gasoline is placed in drums and hauled to the main plant. If the color is good it is put into a stock tank, but if it is off color, i. e., yellow, it is refined in a steam still similar to the method employed at refineries.

Advantage of Pumping Gas from a Well Under a Vacuum—It is a well known fact that the lower the pressure on a liquid the lower the boiling point, and the higher the pressure the higher the boiling point. It is just as essential to compress casinghead gas to a high pressure to condense the gasoline gases, as it is to lower the pressure on the well to lower the boiling point and increase the evaporation of the gasoline in the oil lying in the natural state in the oil sand.

To illustrate: Water will boil at 212 deg. fahr. at sea level or atmospheric pressure of 14.7 lb. per sq. inch. Water in a boiler under pressure of 15 lb. per sq. inch above atmos-

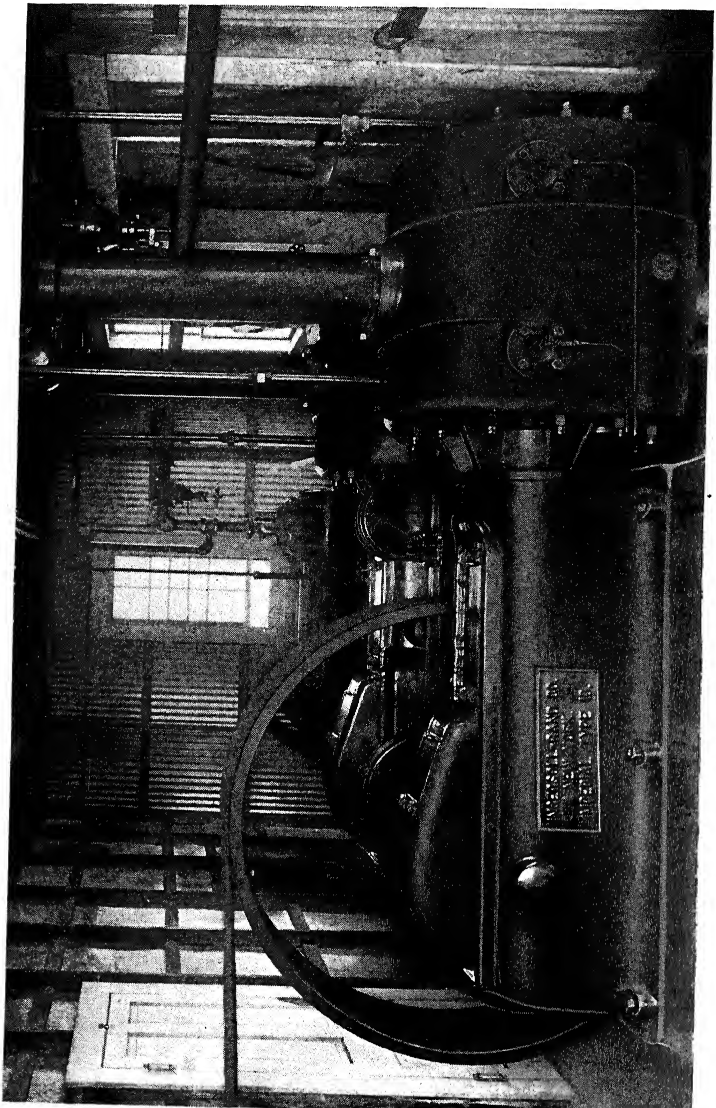


Fig. 15—INTERIOR OF BOOSTER STATION SHOWING VACUUM PUMP AND BOOSTER COMPRESSOR

pheric pressure will boil at a temperature of 249 deg. fahr. and under a pressure of thirty pounds above atmospheric pressure will boil at a temperature of 273 deg. fahr. Likewise when the pressure is lowered to below atmospheric pressure the boiling point of water drops below 212 deg. fahr. With a pressure of 25 in. or 26 in. vacuum the water will boil at 32 deg. fahr.

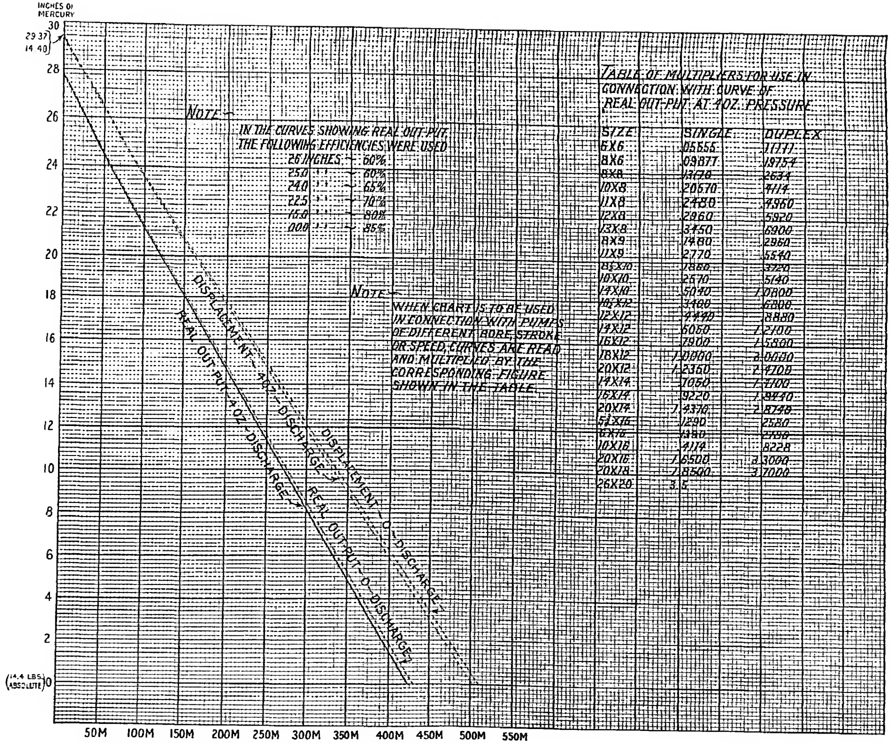
The same theory applies to all hydrocarbons. Therefore it is good practice to apply as great a vacuum as possible on a casinghead gas well, provided the oil sand is not so loose that the vacuum draws the loose sand into the well which would cause trouble.

Placing a vacuum on a casinghead gas well increases both the flow of the oil and the flow of the gas.

Air in Casinghead Gas—It is good policy to take samples of the gas from each of the main field lines monthly or even weekly and to make an analysis of same for oxygen.

Instances have been known to the writer where a gasoline plant after running for several weeks did not produce the quantity of gasoline per thousand cubic feet of gas treated that the preliminary tests, which included the portable compressor tests, showed the gas carried. After an extended investigation of the plant, lines, etc., the trouble was located in defective casingheads, which permitted the entrance of air into the lines due to the vacuum pressure on the wells and lines. It was then evident that the reason for the low production of gasoline from the gas at this particular plant was due to the fact that the plant was receiving a mixture of casinghead gas and air. After the lines and casingheads were placed in gas tight condition the production of gasoline increased to a greater amount per thousand cubic feet of gas treated than the portable compressor test had shown in preliminary tests.

In addition to the production loss at the plant there was a loss through the air passing through the meter and being



Volume per 24 hours in thousands of cubic feet.

Fig. 16—CHART OF CAPACITIES OF VARIOUS SIZED VACUUM PUMPS UNDER DIFFERENT VACUUM CONDITIONS

registered the same as gas. In other words, all the air that leaked into the lines back of the meter was charged for at the same rate as for the gas.

An incident is known to the writer where the analysis of casinghead gas from one well showed as much as 65 per cent air while being pumped under vacuum pressure. This was due to a loose fitting two inch plug in the casinghead.

It is good policy to have the pipe lines on each lease or group of leases so arranged that it is possible to put a pressure on them to determine any leakage. If the natural pressure of the casinghead gas when shut in, does not run up high enough, it is possible to shut the stops on lines running to the lease and connect the residue gas line to them. As the residue gas is generally under a pressure of twenty-five pounds or greater, the test for leakage can be made with this gas.

Invariably the leakage on a system of lines is due to many leaks of small size. All leaks, however small, should be stopped.

It is hardly necessary to mention that a mixture of casinghead gas and air would be liable to cause an explosive mixture, the same as found in a gas engine cylinder. All that would be lacking would be the spark. This might be caused by a pebble rolling along the inside of the pipe and hitting some obstruction.

Eliminating Air from Suction Lines—Air is one of the greatest sources of trouble in the operation of a casinghead plant. It causes trouble in the following ways:

First—**Loss of Production**—The air, in mixing with the casinghead gasoline mixes with vapors of the gasoline and raises the temperature and pressure required to liquefy gasoline constituents to so high a point that the plant cannot properly condense and remove the gasoline.

Second—**Damage to Plant Machinery**—In many plants the most destructive affect of air is its affect upon the

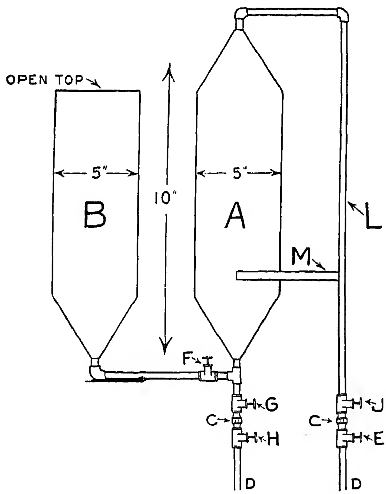
engines, owing to the gasoline not being extracted from the gas and being carried to the engines. A gas engine works in the same manner as a gasoline engine. Most gas engines have too high a compression to take gasoline gas without ignition. Gasoline engines should not have over 75 pounds compression, whereas the gas engines regularly employed in gasoline plants have much more. When the rich mixture of air and casinghead gas strikes the engines, it causes excessive heating in the cylinder due to pre-ignition and quick burning of the charge. This causes frequent shut downs and often it becomes necessary to rebore the cylinders. As the plant becomes older and the vacuum on the sand increases, the engine trouble increases, due to greater leakage of air. Engines have been known to become so hot from running on mixtures of air and gas as to melt the ignition apparatus inside the cylinders. The cost of operating a plant suffering from air troubles run to an excessive figure from engine repairs alone.

THIRD—**Increased Cost of Gas Due to Mixture of Air**—The amount of gas decreases directly in proportion to the amount of air in it and this loss is considerable. However, it is much less than the two above losses. Plants have been built on quantities of gas amounting to three to four hundred thousand cubic feet, and when the air has been eliminated, the amount of gas remaining has fallen to the original, owing to the fact that the gas as originally measured contained more than 50 per cent air.

Most gas pumps will show 9 to 10 per cent air. The ordinary pump in good condition will show not over 14 per cent. Wells and lines on some leases in poor condition will show from 35 to 65 per cent air. Most of this leakage takes place around the casinghead, or in the casing. Stuffing boxes on pumps also cause trouble.

In a general way it may be said that the affects of air accumulative, that is, the admission of air causes other ubles which in turn create still others, until the plant rator has so much trouble on his hands it takes most of profit from the plant operation.

Conversely, removing air will decrease the amount of k to be done by the engines at the plant, the working ssure can be lowered as the gas will be richer and easier work, and the engines will operate under more favorable ditions, as they have better gas on which to do the k.



A—Sample collecting tube or tank.
B—Water storage tank.
C—Three eighth inch union.
D—Three eighth inch tap in gas line.
E, F, G, H, J—Three eighth inch wheel valves.
L—Three eighth inch pipe.
M—Brace to hold L and A in relative position.

7.—APPARATUS FOR TAKING SAMPLE OF GAS FROM PIPE LINE UNDER VACUUM

If air cannot be eliminated, it is best to reduce the compression of the engines by using deeper cylinder heads. Compression rings, owing to the insulating effect of the gaskets adjoining them have a tendency to become hot and cause pre-ignition. Increasing the water flow to the jackets will give some help, also.

Taking Sample of Gas from a Pipe Line under a Vacuum—Figure 17 shows the method of taking a sample of gas from a pipe line under a vacuum pressure.

To take a sample of gas proceed as follows:

Make two three eighths inch taps on top of the gas line the proper distance apart to fit similar connections on the sampling outfit. Screw in each tap a three eighths inch nipple with wheel valve and in each valve screw a short nipple with a half three eighths inch union. The face of the union in each connection should be the same distance from the pipe line.

Before attaching portable sampling outfit to the three eighths inch connections on the pipe line, close valve F, invert apparatus and fill tank A with water while both valves G and J are open. After filling close valves G and J.

Fill the pipe connections on the pipe line between H and C and between E and C with water. Place the apparatus with all the valves closed and connect unions C and C Make sure that there are no leaks in any of the connections.

After attaching apparatus fill the storage tank B to the top with water.

To obtain the sample, open valves G and H and then valves J and E. Water will flow into the pipe line and the gas will flow through pipe L into tank A. After allowing sufficient time for the water to flow out of the tank, close valves G and J and then open valve F, allowing the water to flow from the storage tank B into A. After the water has equalized between A and B close valve. Repeat the

operation of flowing the water from A into the pipe line, by opening valves G and J. This second operation greatly assists in obtaining a true sample.

Close all valves and remove apparatus by disconnecting unions C and C. To overcome the vacuum in the sample of gas, refill B and allow water to flow into A by opening valve F.

Sample of gas can be forced out of pipe L from A into pipette by placing water in B and opening the valve F.

Connections D-H and D-E can be left in the pipe line permanently.

ORSAT APPARATUS FOR DETERMINING OXYGEN AND CARBON DIOXIDE IN NATURAL GAS

By George A. Burrell

"This is an apparatus especially designed for the determination of oxygen and carbon dioxide in casinghead gas at gasoline plants and in lines. Very often the gas as it comes from the wells, is under reduced pressure so that air leaks into the gas if joints in tubing are not tight.

The Orsat apparatus shown at figures 18 and 19 consists essentially of the burette C, the caustic potash pipette A and the Pyro pipette B. A sample tube D is shown connected to the apparatus. The gas is measured in the burette C and then passed into the pipette A, where the carbon dioxide is removed. After again measuring the sample and recording the contraction in volume due to the absorption of carbon dioxide by the caustic potash solution, it is passed into the pyro, pipette B, where the oxygen is removed. The sample is again measured and the amount of oxygen absorbed by the pyro. solution is recorded. From the amount of the oxygen present in the sample the amount of air can be calculated.

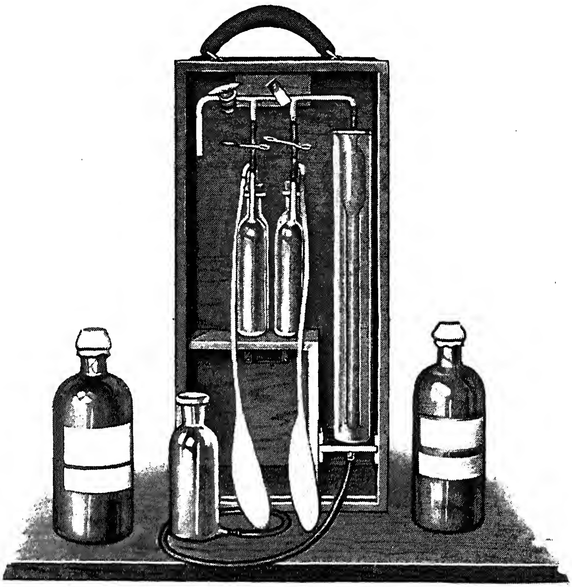


Fig. 18 ORSAT APPARATUS FOR ANALYZING CASINGHEAD GAS FOR OXYGEN

Method of Operation—To charge the apparatus with solutions, water is poured into the bottle H, and from there caused to rise in the burette C by raising H and opening the three-way stop-cock F to the air. When the water has risen in C to about the point M the stopcock F is closed. The bottle H should then be about one fourth full of water.

Caustic potash solution is then poured into the pipette A until the latter is one half full. The solution is poured into the wide mouth opening of the pipette at the rear of the apparatus. The two limbs of the pipette (the pipette is "u" shaped) should be one-half full. When the pipette is filled the pinchcock N and stopcock F should both be open.

The pipette B is filled with "pyro" solution in the same manner. The caustic potash solution in pipette A is drawn up to the etch mark, just below the rubber tubing, by closing the stopcock F and the pinchcock O, opening the pinchcock N, and letting the water fall in the burette C. As this water falls it pulls the solution up in the pipette. To draw the solution clear to the etch mark the level bottle H is lowered. Care must be exercised to draw the solution very slowly and carefully to the etch mark and not by a sudden jerk draw the solution into the stopcock or up into the tube P. To regulate this process the rubber tubing attached to H can be slightly pinched, whereupon the solution will rise in H slowly and evenly.

The "pyro" solution is adjusted in B in the same manner. Rubber bags are provided with each pipette. These are fastened by means of rubber stoppers to the rear of each pipette to keep air from entering the pipettes.

A sample of gas is collected in the sampling tube D, much in the manner described under the heading "Apparatus for Testing Casinghead Gas for Gasoline Content." The sample is collected after the gas has been compressed, because if the natural gas is under much reduced pressure

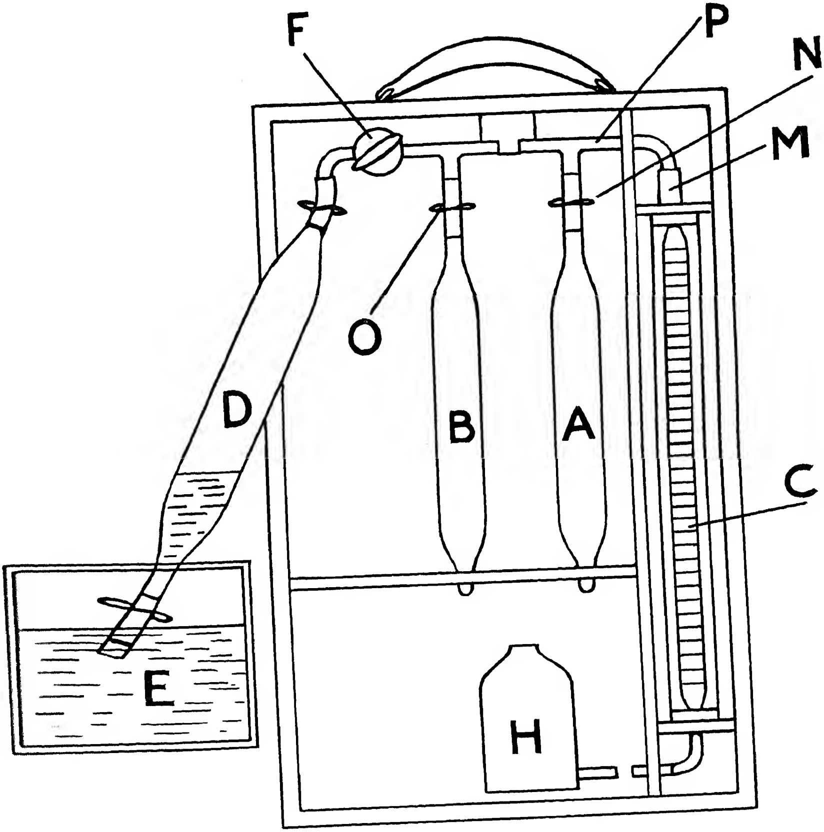


Fig. 19.—SHOWING METHOD OF MAKING ANALYSIS OF CASINGHEAD GAS FOR OXYGEN

between the "plant" and the wells, it will be difficult to collect a sample at the latter place. The sample tube filled with water is attached to a petcock somewhere in the "plant" where the gas is under pressure, the petcock opened, the water forced out, and the gas allowed to blow through the sample tube for several minutes. The pinch-cocks on each end of the sample tubes are then closed and the sample carried to the Orsat apparatus for analysis.

The sample tube D is attached to the apparatus as shown with its lower end dipping in a basin of water. Previous to this the burette C should be filled with water to the mark M and the pipettes A and B filled with solution to the etch marks just below the rubber tubing on each pipette.

To transfer the sample from the pipette D to the burette C, the pinchcocks on the sample tube, and the stop-cock F are opened, whereupon the water will fall in the burette C and rise in the sample tube D, the gas passing from the tube D into the burette C. When approximately 100 c. c. of gas have passed into C, the stopcock F and the pinchcocks on the sample tube are closed. Next the gas in the burette is measured by holding the bottle H so the level of the water in it is on a line with the level of the water in the burette. The number of cubic centimeters of gas are then read on the burette. Next the gas is passed into the pipette A by raising the level bottle H, and opening the pinchcock on the pipette A. The water in C will rise and the caustic potash solution in A will fall, the gas passing from the burette C to the pipette A. The water in C is allowed to rise to the point M. The caustic potash solution will then react with the carbon dioxide in the gas sample and remove it from the sample. The gas is allowed to remain in contact with the caustic potash solution about three minutes. Then the gas is passed back into the burette and again measured. The contraction in volume shows the

cubic centimeters of carbon dioxide that have been removed from the gas.

The gas is next passed into the "pyro" pipette and the oxygen removed from the gas sample. It is best to pass the gas sample back and forth between the burette and "pyro" pipette until no more oxygen is removed as determined by successive readings of the sample in the burette. "Pyro" removes oxygen more slowly than caustic potash removes carbon dioxide.

The caustic potash solution can be used for a great number of determinations, while the "Pyro" solution should be renewed more often, depending of course on the oxygen content of the samples that are tested. It should be occasionally tried out by analyzing a sample of atmospheric air. The latter contains 20.9 per cent oxygen. "Pyro" solution also removes carbon dioxide from a gas mixture, hence if it is not removed first by means of caustic potash solution, it will be removed by the "Pyro" and misleads the analyst into believing there is more oxygen present in the mixture than the true amount.

The following example shows the method of calculation:

Method of Calculating Orsat Analysis.

	c. c.
Sample taken for analysis	95.0
Volume after absorption in caustic potash solution	94.1
Carbon dioxide	0.9
Volume after "Pyro" absorption	90.0
Oxygen	4.1

These values become as follows when calculated to a percentage basis.

$$\text{Carbon dioxide} = \frac{0.9}{95} \times 100 = 0.9 \text{ per cent.}$$

$$\text{Oxygen} = \frac{4.1}{95.0} \times 100 = 4.3 \text{ per cent.}$$

The air in the sample becomes:

$$\frac{4.3}{20.9} \times 100 = 20.6 \text{ per cent.}$$

Tank for Separating Gas from Oil Flowing from Well—Tanks are often used on oil leases showing large quantities of gas where the oil flows or is pumped. The gas taken from the oil is of first-class quality to run a gas engine at the power house, or could be compressed to extract the gasoline, provided there is a sufficient quantity of gas to make it pay. The separating tank should be set high enough to allow the oil, after separation, to flow freely to the regular oil tanks.

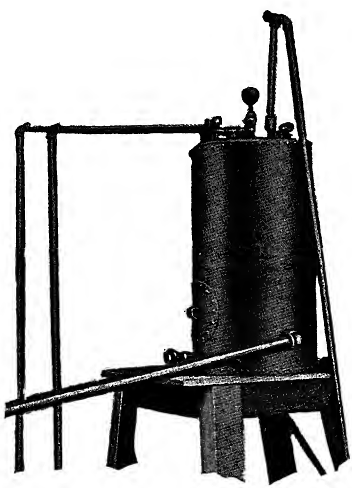


Fig. 20
AUTOMATIC OIL AND GAS SEPARATOR

PART FOUR

Construction of Pipe Lines

Little need be said on this subject, as it is a very familiar one to all gas and oil men.

Seldom are the lines very long or very large in diameter. Most of the lines in use are from two inch to eight inch.

As the pressure is often many inches of mercury below atmospheric pressure, though the gas volumes to be carried are generally small, considerably larger lines are required than if the same volume of gas were carried at a pressure much higher than atmospheric.

Pipe lines should be large, thereby decreasing the loss in pressure between the vacuum pumps and the wells and increasing the vacuum in the wells due to less friction in large lines.

While plain end pipe is occasionally used to transport casinghead gas, screw pipe is more commonly used. The effect of free gasoline on the rubber rings used on plain end pipe, quickly rots the rubber and creates leaks. With the screw joint, gasoline has also a tendency to cut the asphaltum paint used on the thread and this creates small leaks.

When screw pipe is used, thick shellac is better than asphaltum to use on the pipe threads. In addition it is good policy to use collar leak clamps on every joint.

With welded pipe joints, all liability of leaks is eliminated. The reader will appreciate that deposited gasoline, which is always found in casinghead gas pipe lines, is a very difficult liquid to control, consequently the advantage of the welded joint over the plain end and screwed joints should open a very large field for the former.

Welding Gas Lines—In welding gas lines, the pipe is strung along on top of the ground, outside of the trench.

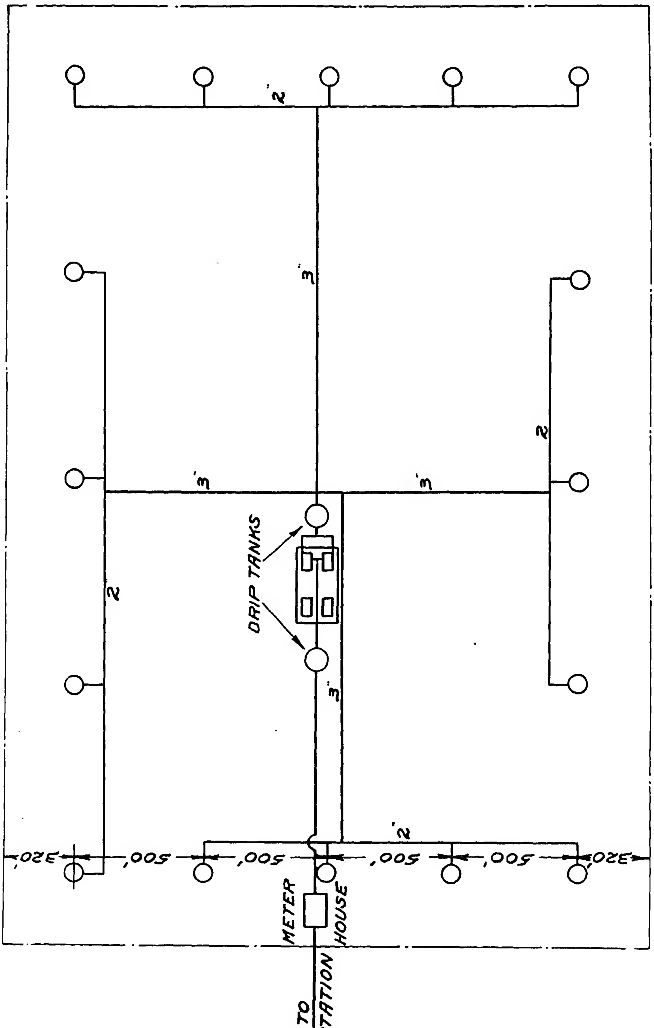


Fig. 22—PLAN OF PIPE LINE SYSTEM ON AN OIL WELL LEASE

Two or more lengths of pipe are butted together and welded by an operator, assisted by two helpers, one at each end of the section. The helpers turn the section with chain tongs or other devices so that the operator is always welding on top of the pipe—a position in which the fastest work can be accomplished.

Various engineers use different methods of handling the pipe for welding. While many follow the method described above for all sizes of pipe, some engineers weld the larger sizes, namely, 8, 10 and 12 inches, supported on skids directly above the trench. In this way frequently two operators work on opposite sides of the pipe, which is turned, as the work progresses, by one or more helpers.

With the small oxy-acetylene flame, which has a temperature of approximately 6300 degrees, the metal on each side of the joint is heated to the fusion point, when pure Norway iron wire is fused into the molten metal, forming a true fusion weld. By this simple method the operator does the work, building up the weld to any desired thickness, making the joint as strong as desired.

Where the pipes are cut off straight, the two sections are butted up to within $\frac{1}{16}$ to $\frac{1}{4}$ inch of each other according to the size of the pipe, and the weld is made as described.

Fig. 22 illustrates a welding unit most suitable for field use. The unit consists of two steel cylinders, one each of compressed acetylene and oxygen, welding blow-pipe, necessary regulators, hose, etc. The entire outfit is mounted on a two-wheeled truck and is easily and quickly moved from place to place as required.

As fast as a section of welded pipe is finished it is capped at both ends and tested for leaks, under any desired pressure.

After the welded section has been tested and found satisfactory, it is rolled to the trench and lowered into place.

Although the pipe in the trench should be graded as carefully as is customary in ordinary practice, no care need

be taken to have it lie absolutely straight. In fact the more snake-like the pipe lies in the trench, the better, as by this method contraction and expansion are taken care of. Common practice has demonstrated that because of the great strength and flexibility of the welded joint this is the only provision necessary to take care of expansion and contraction.

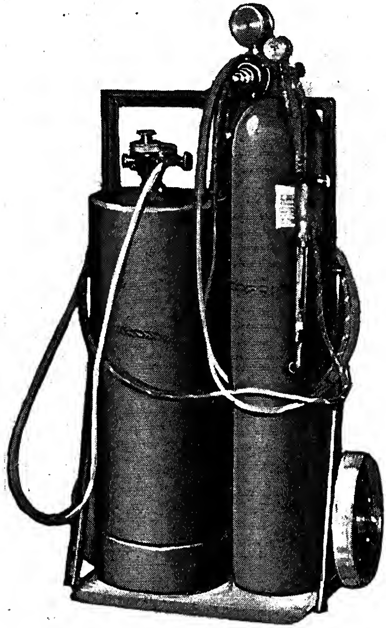


Fig. 22 —PORTABLE WELDING OUTFIT CONSISTING OF TWO STEEL CYLINDERS —ONE OF OXYGEN AND ONE OF ACETYLENE WITH REGULATORS, HOSE, ETC.

The section of pipe now in the trench is welded to the main already laid. For this, as for all welding in the trench, a bell hole is dug large enough to allow the operator to weld entirely around the joint. When welding the bottom of the pipe he is working overhead, a position in which good welding is readily accomplished after proper practice.

Where laterals are required, a hole of the proper size is cut in the main with the cutting blowpipe, and the lateral is welded into place at any angle desired.

One of the great advantages in this method of pipe line construction is the eliminating of joints, collars, sleeves, fittings, etc., thus greatly decreasing the leakage.

COMPARATIVE CAPACITY OF PIPES OF DIFFERENT GAS APPLIED TO LINES IN WHICH A

Size of Pipe In.	1	2	3	4	5	6	8
	Comparative Note—In making computations observe						
1	1	34	265	1,150	3,573	9,035	39,000
2	.0294	1	7.8	34	105	266	1,150
3	.0037	.128	1	4.34	13.45	34	147
4	....	.0295	.231	1	3.11	7.80	34
5	....	....	.0741	.3274	1	2.51	10.94
6	....	....	.0293	.1272	.3954	1	4.34
8	....	....	.0037	.0295	.0915	.2316	1
10	....	....	....	.0094	.0295	.0741	.3260
12	....	....	....	....	.0116	.0295	.1272
15¼	....	....	....	....	....	.0086	.0373
16	....	....	....	....	....	....	.0295
17¼	....	....	....	....	....	....	....
18	....	....	....	....	....	....	....
19¼	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....

The above table is based upon the fact that the length of pipes for the same quantity of gas varies as the 5.0835 power of their diameters. The value of the increasing or decreasing sizes can readily be appreciated by an inspection of the table.

It is particularly useful in securing the value of a series of different sizes of pipes in the same line by reducing the values of the several sizes to some one of the sizes in use. For example, on the horizontal line in the table a unit, say 1 foot or 1 mile of 8 inch pipe,

DIAMETERS CONVEYING THE SAME QUANTITY OF NUMBER OF DIFFERENT SIZES ARE USED

(By F. H. Oliphant)

10	12	15¼	16	17¼	18	19¼	20

VALUES
carefully the decimal notations.

121,210	306,380	1,043,700	1,326,000	1,937,700	2,406,100	3,382,300	4,120,000
3,570	9,035	30,700	39,000	57,000	70,765	99,480	121,178
457	1,150	3,940	5,004	7,312	9,040	12,760	15,550
105	265	908	1,150	1,685	2,092	2,940	3,575
34	85.75	292	371	542.3	673.4	946.6	1,150
13.45	34	115.5	147	215	265	375	457
3.11	7.80	26.75	34	50	61.70	86.70	105
1	2.52	8.61	10.94	16	19.85	27.90	34
.3954	1	3.41	4.34	6.32	7.80	11.00	13.45
.1161	.2935	1	1.27	1.85	2.30	3.24	3.95
.0915	.2316	.7871	1	1.46	1.81	2.55	3.11
.0630	.1582	.5386	.6843	1	1.24	1.75	2.13
....	.1273	.4337	.5510	.8053	1	1.41	1.71
....	....	.3085	.3920	.5728	.7113	1	1.22
....	....	....	.3218	.4703	.5840	.8209	1

has the same value as 3.11 feet or miles of 10 inch, 7.80 feet or miles of 12 inch and 105 feet or miles of 20 inch.

When smaller sizes are used 1 foot or 1 mile of 8 inch pipe is equivalent to 0.2316 feet or mile of 6 inch pipe, etc.

Larger diameters, when compared to smaller, give the equivalent in an increased length, and smaller diameters give a less length when compared with a diameter assumed to be 1.

Pipe Line Losses—With many of the large gasoline plants, the gas is not only measured at the gas producing leases where it is purchased, but also through one or more large meters at the plant. If there was no condensation of the casinghead gas in the pipe line between the leases and the plant, the lease meters and the plant meter should check within a very small per cent of one another. Nearly all field lines are equipped with drips that collect gasoline condensed in the lines. This condensation is caused through changes in temperature, not only between day and night temperatures but also from different parts of the lines being exposed to the atmosphere while other parts are either covered or buried. The greatest amount of condensation occurs in cold weather. The drips are pumped or "blown off" and the gasoline and light oils are saved for refining into gasoline.

When checking lease meters with a plant meter, due consideration must be given to drip accumulation. Between 32 to 42 gallons of gasoline will make 1,000 cubic feet of gasoline vapor or gas.

The number of gallons of gasoline in one thousand cubic feet of gas varies with the gravity of the gasoline.

Pipe Line Drips—The heavy hydrocarbons in casinghead gas are easily condensed in pipe lines due to the gas coming in contact with a cold section of pipe line. The pipe line temperatures vary according to their location above or below the surface and according to the temperatures of the ground and the atmosphere. It is very important to install drips along the lines, especially in low spots.

Accumulations from drips should be drawn off and refined. Often they are of a yellowish tint which color comes from the oil in the well. If gasoline is found clear in color, it can be put into stock tanks but if off color, it is necessary to refine it. By distilling in a steam still, the same as employed at a refinery, the gasoline recovered will be of

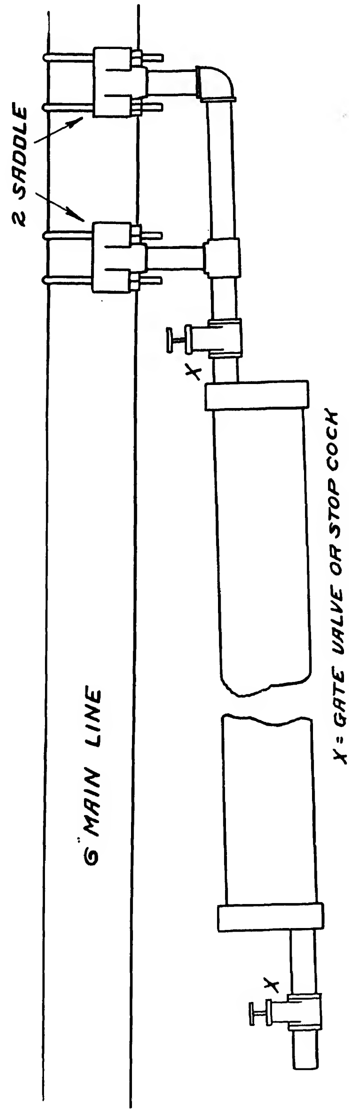


Fig 23—PLAN OF A DRIP FOR USE ON PIPE LINE UNDER VACUUM

STANDARD DIMENSIONS, CAPACITY AND WEIGHT OF WROUGHT IRON PIPE FOR STEAM, GAS, OIL OR WATER

Diameters, Inches			Thickness of Pipe Inch	Outside Diameter of Coup'gs Inches	Feet of Pipe for 1 Cu. Ft. Volume	Weight of Pipe per Ft. Pounds	No. of Threads per Inch
Nom. Inside	Actual Inside	Actual Outside					
1/8	.270	.405	.068	.510	2500.	.243	27
1/4	.364	.54	.086	.720	1385.	.422	18
3/8	.494	.675	.091	.844	751.5	.561	18
1/2	.623	.84	.109	1.156	472.4	.845	14
3/4	.824	1.05	.113	1.375	270.	1.126	14
1	1.048	1.315	.134	1.625	166.9	1.670	11½
1¼	1.380	1.66	.140	2.125	96.25	2.258	11½
1½	1.611	1.9	.145	2.375	70.65	2.694	11½
2	2.067	2.375	.154	2.937	42.36	3.667	11½
2½	2.468	2.875	.204	3.500	30.11	5.773	8
3	3.067	3.5	.217	4.062	19.49	7.547	8
3½	3.548	4.	.226	4.687	14.56	9.055	8
4	4.026	4.5	.237	5.187	11.31	10.728	8
4½	4.508	5.	.247	5.750	9.03	12.492	8
5	5.045	5.563	.259	6.343	7.20	14.564	8
6	6.065	6.625	.280	7.343	4.98	18.767	8
7	7.023	7.625	.301	8.437	3.72	23.410	8
8	7.982	8.625	.322	9.375	2.88	28.348	8
9	9.001	9.688	.344	10.560	2.26	34.077	8
10	10.019	10.75	.366	11.680	1.80	40.641	8
12	12.000	12.75	.375	13.930	1.27	49.000	8

proper color and of good quality though not as high in gravity as that obtained from the compression method. This is due to the fact that uncondensed vapors escape in the process of distilling. These vapors are those portions of gasoline that are the most volatile.

Fig. 23 shows a gasoline drip for a pipe line when the pressure of the gas is below the atmospheric pressure. If the pressure of the gas is above the atmosphere only one gate is necessary and that should be placed at the blow-off.

To blow the drip when the pressure of the gas is below atmospheric pressure, close the gate nearest the pipe line

and then open the "blow-off" gate. After the drip is drained close the "blow-off" gate and open the gate next to the pipe line.

A drip should be placed at a low spot in the line. The length of the drip is dependent upon the amount of gasoline that is condensed in the line. The drip can be made up of several joints of pipe instead of one. Extra long drips can be placed on small sized lines, if desired.

Formula for Computing the Flow of Natural Gas in Pipe Lines—Based upon formula by F. H. Oliphant in "Production of Natural Gas in 1900," United States Geological Survey.

$$\text{Formula—}Q = 42a.\sqrt{\frac{P_1^2 - P_2^2}{L}}$$

Q = cubic feet per hour.

42 = constant.

a = computed value for diameters.

L = length of line in miles.

P_1 = gauge pressure + 14.4 pounds at intake end of line.

If the gas is under a vacuum, $P_1 = 14.4$—gauge pressure at the intake end of the line.

P_2 = gauge pressure + 14.4 pounds at discharge end of line.

If the gas is under a vacuum $P_2 = 14.4$—gauge pressure at the discharge end of the line.

Do not use inches of mercury for the value of P_1 and P_2. Reduce the inches of mercury to lb. One inch of mercury equals .4908 lb.

For value of a, see Table of Multipliers on page 90.

Specific gravity of gas taken at 1.0. For any other specific gravity multiply final result by $\sqrt{\frac{1.0}{\text{sp.gr.gas}}}$

For other diameters, or value A, use the following multipliers:

¼ inch	.0317	2¼ inches	10.37	8 inches	198.0
½ inch	.1810	3 inches	16.50	10 inches	350.0
¾ inch	.5012	4 inches	34.10	12 inches	556.0
1 inch	1.0000	5 inches	60.00	16 inches	1160.0
1½ inches	2.9300	5⅝ inches	81.00	18 inches	1570.0
2 inches	5.9200	6 inches	95.00		

For pipes greater than 12 inches in diameter the measure is taken from the outside and for pipes of ordinary thickness the corresponding inside diameters and multipliers are as follows:

Outside	Inside	Multiplier
15 inch	14¼ inch	863
16 inch	15¼ inch	1025
18 inch	17¼ inch	1410
20 inch	19¼ inch	1860

For riveted or cast pipe with inside diameters as below, use multipliers opposite:

20 inch	2055	30 inch	5830
24 inch	3285	36 inch	9330

All pipe line capacity tables on pages 91 to 104 are based on the foregoing formula.

Pipe Line Capacities for Gas at a Vacuum and Pressure. Specific Gravity=1. For other Specific Gravities see table, page 105.

Capacity of 2 in. Pipe Line, 1 Mile Long, for 24 Hours.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	18							
15	30	24						
10	42	38	29					
5	54	51	44	33				
Lb. per sq. in.								
0	67	62	58	50	37			
3	79	77	73	67	58	44		
6	93	92	88	83	76	66	49	
10	112	110	107	103	98	91	78	
25	181				173	169	163	142

Capacity of 2 in. Pipe Line, 2 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	13							
15	21	17						
10	30	27	20					
5	38	36	31	23				
Lb. per sq. in.								
0	46	44	41	35	26			
3	56	54	51	47	41	31		
6	66	65	62	58	54	47	34	
10	79	78	76	73	69	64	55	
25	128				122	119	114	100

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 2 in. Pipe Line, 3 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	10							
15	17	14						
10	24	22	17					
5	31	29	25	19				
Lb. per sq. in. 0	37	36	33	28	21			
3	46	44	42	38	34	26		
6	54	52	51	47	44	38	28	
10	65	64	61	59	56	52	45	
25	104				100	97	94	82

Capacity of 3 in. Pipe Line, 1 Mile Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	52							
15	86	68						
10	110	106	82					
5	150	141	124	93				
Lb. per sq. in. 0	187	175	161	139	103			
3	222	215	205	188	162	125		
6	261	256	246	232	212	185	136	
10	312	308	301	289	273	253	220	
25	505				482	471	454	397

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 3 in. Pipe Line, 2 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	36							
15	61	48						
10	84	75	58					
5	106	100	88	65				
Lb. per sq. in. 0	129	124	114	98	73			
3	157	152	144	132	115	89		
6	184	181	174	164	150	131	96	
10	221	218	212	204	193	179	155	
25	357				341	333	320	280

Capacity of 3 in. Pipe Line, 3 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	30							
15	49	39						
10	68	61	47					
5	87	82	71	54				
Lb. per sq. in. 0	105	101	93	80	59			
3	128	124	118	108	93	72		
6	150	147	142	133	123	107	78	
10	180	178	173	167	157	146	126	
25	292				278	272	262	229

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 3 in. Pipe Line, 4 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	26							
15	43	34						
10	59	53	41					
5	75	71	61	46				
Lb. per sq. in. 0	91	88	80	69	51			
3	111	108	102	93	81	62		
6	130	127	123	116	106	92	68	
10	156	154	150	144	136	126	109	
25	252				240	235	226	198

Capacity of 4 in. Pipe Line, 1 Mile Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	107							
15	177	142						
10	246	221	169					
5	311	293	256	192				
Lb. per sq. in. 0	387	363	334	287	213			
3	459	446	423	387	336	260		
6	539	528	509	480	439	384	283	
10	646	637	621	598	565	523	455	
25	1045				997	973	938	821

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 4 in. Pipe Line, 2 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	76							
15	126	100						
10	173	156	119					
5	221	207	181	136				
Lb. per sq. in. 0	267	256	236	203	150			
3	324	315	299	273	238	183		
6	381	373	359	339	311	271	200	
10	456	450	439	422	400	370	321	
25	739				705	688	662	579

Capacity of 4 in. Pipe Line, 3 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	62							
15	102	81						
10	142	127	97					
5	180	169	148	111				
Lb. per sq. in. 0	218	209	192	166	123			
3	265	257	249	223	194	150		
6	311	304	294	277	253	222	163	
10	373	368	359	345	326	302	263	
25	576				563	560	542	473

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 4 in. Pipe Line, 4 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	53							
15	89	71						
10	122	110	84					
5	156	147	128	96				
Lb. per sq. in. 0	189	181	167	143	106			
3	229	222	211	194	167	130		
6	269	264	254	239	219	191	141	
10	323	318	311	298	283	262	227	
25	521			508	497	486	468	409

Capacity of 4 in. Pipe Line, 5 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	48							
15	79	63						
10	109	99	75					
5	139	131	114	85				
Lb. per sq. in. 0	169	162	149	128	95			
3	205	199	189	173	150	115		
6	241	236	227	215	196	171	126	
10	287	284	277	267	253	234	203	
25	465			454	444	436	420	369

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 6 in. Pipe Line, 1 Mile Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	300							
15	495	395						
10	685	616	472					
5	867	817	715	537				
Lb. per sq. in. 0	1080	1011	931	802	595			
3	1279	1243	1179	1080	937	723		
6	1503	1473	1419	1338	1226	1071	789	
10	1801	1776	1731	1665	1576	1459	1267	
25	2912			2831	2779	2712	2616	2290

Capacity of 6 in. Pipe Line, 2 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	212							
15	351	279						
10	484	435	333					
5	615	578	506	380				
Lb. per sq. in. 0	746	715	658	567	423			
3	904	880	834	763	663	510		
6	1062	1041	1003	946	866	756	558	
10	1273	1256	1224	1178	1115	1032	896	
25	2061			2017	1967	1919	1845	1615

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 6 in. Pipe Line, 3 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	173							
15	286	227						
10	395	355	272					
5	502	472	413	310				
Lb. per sq. in. 0	609	584	537	463	344			
3	738	718	681	623	543	417		
6	867	850	819	772	707	618	455	
10	1039	1025	1000	962	910	842	732	
25	1684			1635	1606	1569	1512	1319

Capacity of 6 in. Pipe Line, 4 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	149							
15	248	197						
10	342	308	236					
5	435	408	357	268				
Lb. per sq. in. 0	527	506	465	400	297			
3	639	622	589	540	469	362		
6	751	736	709	669	613	535	394	
10	900	887	866	832	788	729	633	
25	1452			1415	1386	1356	1304	1141

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 6 in. Pipe Line, 5 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	134							
15	222	176						
10	306	275	211					
5	389	366	319	240				
Lb. per sq. in. 0	471	452	416	359	266			
3	572	556	527	483	419	321		
6	672	658	634	598	547	479	352	
10	800	794	774	745	705	653	566	
25	1297			1267	1237	1215	1171	1030

Capacity of 6 in. Pipe Line, 6 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	122							
15	202	161						
10	279	251	192					
5	355	333	291	219				
Lb. per sq. in. 0	430	413	380	327	243			
3	522	507	481	441	383	295		
6	613	601	579	546	498	437	321	
10	735	725	706	680	643	595	517	
25	1190			1156	1135	1108	1069	935

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 6 in. Pipe Line, 8 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	105							
15	175	139						
10	242	217	167					
5	307	288	253	190				
Lb. per sq. in.								
0	372	357	328	284	210			
3	455	439	417	382	331	256		
6	531	520	501	472	433	378	278	
10	636	627	612	589	557	516	448	
25	1030			1001	983	957	925	807

Capacity of 6 in. Pipe Line, 10 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	94							
15	157	124						
10	216	195	149					
5	274	258	226	170				
Lb. per sq. in.								
0	333	319	294	253	188			
3	404	393	373	342	296	229		
6	475	465	448	423	387	339	249	
10	569	561	547	527	498	461	400	
25	923			896	879	859	827	724

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 8 in. Pipe Line, 1 Mile Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	625							
15	1033	824						
10	1428	1284	983					
5	1807	1704	1491	1120				
Lb. per sq. in. 0	2252	2109	1940	1672	1242			
3	2666	2592	2458	2252	1954	1508		
6	3132	3070	2958	2789	2554	2232	1644	
10	3753	3702	3609	3472	3286	3042	2433	
25	6070			5901	5792	5653	5453	4773

Capacity of 8 in. Pipe Line, 2 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	443							
15	732	582						
10	1010	907	695					
5	1283	1205	1054	792				
Lb. per sq. in. 0	1555	1491	1372	1182	878			
3	1886	1833	1738	1592	1382	1066		
6	2215	2171	2091	1972	1806	1578	1163	
10	2653	2617	2551	2455	2324	2151	1868	
25	4296			4204	4099	4000	3846	3367

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 8 in. Pipe Line, 3 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	361							
15	597	474						
10	824	741	568					
5	1047	983	860	647				
Lb. per sq. in. 0	1269	1217	1120	965	717			
3	1540	1496	1419	1299	1128	870		
6	1808	1773	1707	1610	1474	1288	949	
10	2167	2137	2083	2004	1897	1756	1525	
25	3511			3409	3347	3270	3151	2749

Capacity of 8 in. Pipe Line, 4 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	312							
15	517	412						
10	713	641	492					
5	906	852	745	560				
Lb. per sq. in. 0	1099	1054	970	836	620			
3	1333	1296	1229	1126	976	754		
6	1566	1535	1479	1394	1277	1116	822	
10	1876	1851	1804	1736	1643	1521	1321	
25	3027			2950	2888	2826	2718	2378

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 8 in. Pipe Line, 5 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	279							
15	463	367						
10	637	574	439					
5	811	762	667	500				
Lb. per sq. in. 0	982	942	867	748	555			
3	1192	1159	1099	1007	873	669		
6	1401	1373	1322	1247	1142	998	735	
10	1668	1655	1613	1552	1469	1360	1180	
25	2703			2641	2579	2533	2440	2147

Capacity of 8 in. Pipe Line, 6 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	254							
15	421	336						
10	582	523	401					
5	739	695	608	457				
Lb. per sq. in. 0	897	860	792	682	506			
3	1089	1058	1003	919	797	616		
6	1279	1253	1207	1138	1037	911	671	
10	1532	1511	1473	1417	1342	1242	1078	
25	2480			2411	2366	2310	2229	1949

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Capacity of 8 in. Pipe Line, 8 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	220							
15	366	290						
10	505	453	347					
5	641	602	527	396				
Lb. per sq. in. 0	777	745	685	591	438			
3	950	916	869	796	691	533		
6	1107	1085	1045	986	903	789	581	
10	1326	1308	1276	1227	1161	1075	734	
25	2147			2086	2049	1995	1929	1682

Capacity of 8 in. Pipe Line, 10 Miles Long, for 24 Hours. Specific Gravity of Gas=1.

Intake Pressure	Discharge Pressure							
Inches of Mercury Vacuum	Inches of Mercury Vacuum					Lb. per sq. in.		
	25	20	15	10	5	0	3	10
20 in.	197							
15	327	259						
10	451	405	311					
5	573	538	471	354				
Lb. per sq. in. 0	695	667	613	528	392			
3	843	819	777	712	617	476		
6	990	971	934	882	808	705	520	
10	1186	1171	1141	1098	1039	962	835	
25	1921			1867	1832	1790	1725	1510

All capacities are given in thousands.
For other specific gravities, apply multiplier found in table, page 105.

Multipliers to be Used for Gas of Specific Gravity Other than 1.00.

Specific Gravity	Multiplier	Specific Gravity	Multiplier
0.6	1.29099	1.20	0.91287
0.65	1.24034	1.25	0.89442
0.7	1.19522	1.30	0.87705
0.75	1.15470	1.35	0.86066
0.8	1.11803	1.40	0.84515
0.85	1.08465	1.45	0.83045
0.9	1.05409	1.50	0.81649
0.95	1.02597	1.55	0.80321
1.00	1.00000	1.60	0.79056
1.05	0.97589	1.65	0.77849
1.10	0.95346	1.70	0.76696
1.15	0.93250		

PART FIVE

MEASURING CASINGHEAD GAS

When gasoline gas is purchased by the cubic foot it is necessary to provide some means of securing an accurate measurement of it. A meter is also desirable for checking the efficient operation of the plant. A casinghead gas meter is built for this character of work whether the gas measured is under pressure or a vacuum.

It is only necessary to keep the meter clean and note the condition of the diaphragms from time to time. If the gas is measured at vacuum pressure, either straight recording pressure or recording volume and pressure gauges are necessary.

In installing meters for this work it is essential to set the meter far enough away from the compressor so that the pulsation of the piston will not be felt in the meter.

Table to Determine the Proper Size Meter in Measuring Gas at a Vacuum Pressure, in Inches of Mercury, where the Maximum Volume per 24 Hours or per Hour is Given at Four Ounce Pressure Above an Atmospheric Pressure of 14.4 Lb. per Square Inch.

Maximum Volume Per 24 Hours	Maximum Volume Per Hour	Size of Meter Required to Measure Different Volumes at Different Vacuum Pressures			
		5 in.	10 in.	15 in.	20 in.
50,000	2,080	3M	3M	6M	10M
100,000	4,160	6M	10M	10M	20M
150,000	6,250	10M	10M	20M	20M
200,000	8,330	10M	20M	20M	35M
250,000	10,410	20M	20M	20M	35M
300,000	12,500	20M	20M	35M	50M
400,000	16,660	20M	35M	35M	50M
500,000	20,830	35M	35M	50M	75M
600,000	25,000	35M	50M	50M	75M
800,000	33,330	50M	50M	75M	100M
1,000,000	41,660	50M	75M	100M	125M
1,500,000	62,500	75M	100M	125M	*200M
2,000,000	83,300	100M	125M	*200M	*275M

* Means use two or more meters in battery form.

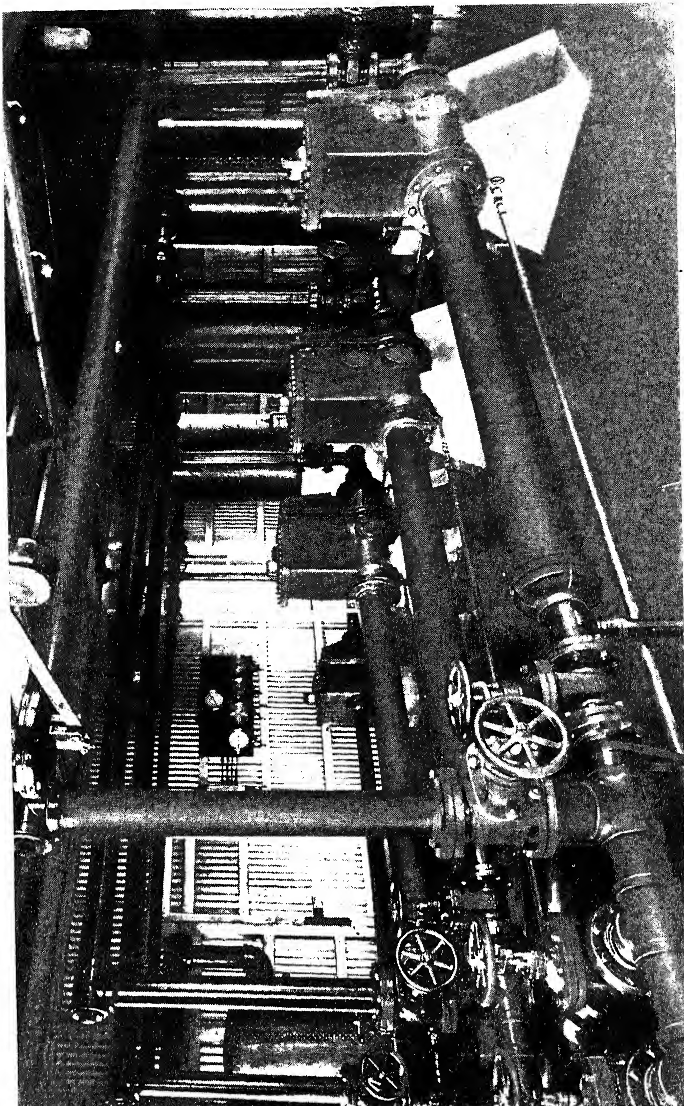


Fig. 24—CASINGHEAD GAS MEASURING STATION. *Note by-pass and tee ahead of meter to permit testing meter with residue gas*

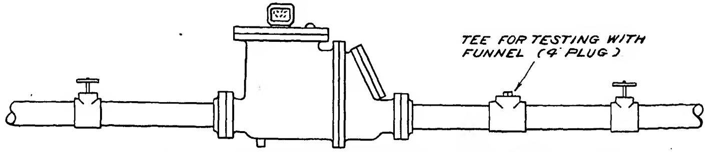


Fig. 25—INSTALLATION OF A METER FOR MEASURING CASINGHEAD GAS

To Read a Meter—In reading a meter the small or 100-foot dial should not be considered. Each sub-division in the circle represents one tenth of the figures placed above the circle. In other words, on the 10,000 dial, if the hand points between 7 and 8, the figure the hand has just passed (which would be 7) indicates that over 7,000 cubic feet have passed. The 1,000-foot dial is only taken into consideration when the hand points between 5 and 0, in which case it is counted as 1,000. In the foregoing case, if the hand on the 10,000-foot dial was close to 8 and the hand in the 1,000-foot dial pointed at 8 or 9, the reading of the 10,000-foot dial would be 8,000. Each dial above the 10,000-foot dial is read the same as the 10,000-foot dial above described.

In reading the dial no attention should be paid to the wording "one per cent" or "two per cent" printed on the face of the dial. The wording is intended for use when ordering new clock or tally, and has no bearing on the meter reading.

Proper Sized Meter to Install Where Gas is Used to Generate Power Either in a Gas Engine or Under Steam Boilers

Horse-power of Engine or Boilers	Capacity of Meter In Cu. Ft. per Hour		Horsepower of Engine or Boilers	Capacity of Meter In Cu. Ft. per Hour	
	In Gas Engine	Under Steam Boiler		In Gas Engine	Under Steam Boiler
10	500	800	150	3,000	10,000
15	500	1,500	200	6,000	20,000
20	800	1,500	300	6,000	20,000
25	800	3,000	400	10,000	35,000
35	1,500	3,000	500	10,000	35,000
50	1,500	6,000	600	10,000	50,000
75	3,000	6,000	800	20,000	50,000
100	3,000	10,000	1,000	20,000	75,000

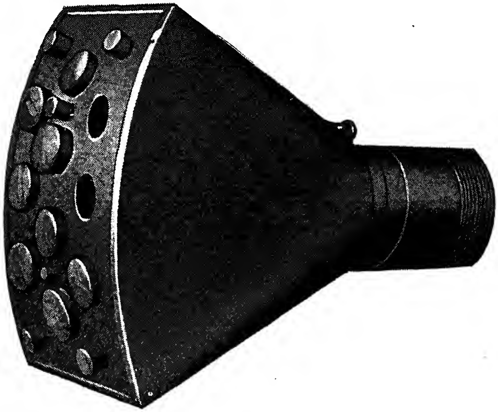


Fig. 26—FUNNEL METER FOR PROVING METERS IN THE FIELD

Proving Meters in the Field—In proving meters in the field use residue gas. Take the specific gravity of the gas twice daily, even though working on one meter. The gravity of the residue gas will run as high as 1.1 or higher, even after the gasoline has been extracted. This is due to the fact that some of the hydrocarbons that have been extracted evaporate in the accumulator tank and pass out with the residue gas. The gravity of the residue gas will be highest in warm weather.

Greater caution should be used in proving with this gas, than with natural gas, as the residue gas, being so heavy, will hang near the ground and not rise. Do not run any tests within a building.

The error generally allowed in the field is 3 per cent fast or slow, while the factory is confined to a two per cent error either fast or slow.

PRESSURES TO BE USED IN MEASURING AIR BAROMETRIC PRESSURES

Standard barometer..........29.2 inches Standard temperature...

deg. fahr.	Barometer Reading														
	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0
	Pressure in Inches of Water														
30	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.35	4.36	4.38	4.39	4.40	4.42	4.44
31	4.22	4.24	4.25	4.27	4.28	4.29	4.31	4.32	4.34	4.35	4.37	4.38	4.39	4.41	4.43
32	4.21	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.34	4.36	4.37	4.39	4.40	4.42
33	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.31	4.32	4.34	4.35	4.37	4.38	4.39	4.41
34	4.20	4.21	4.22	4.24	4.25	4.27	4.28	4.30	4.31	4.33	4.34	4.36	4.37	4.39	4.40
35	4.19	4.20	4.22	4.23	4.25	4.26	4.27	4.29	4.30	4.32	4.33	4.35	4.36	4.38	4.39
36	4.18	4.19	4.21	4.23	4.24	4.25	4.27	4.28	4.30	4.31	4.32	4.34	4.35	4.37	4.38
37	4.17	4.18	4.20	4.21	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.34	4.36	4.37
38	4.16	4.17	4.19	4.21	4.22	4.23	4.25	4.26	4.28	4.29	4.31	4.32	4.34	4.35	4.37
39	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25	4.27	4.28	4.30	4.31	4.33	4.34	4.36
40	4.14	4.15	4.17	4.19	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.30	4.32	4.33	4.35
41	4.14	4.15	4.17	4.18	4.19	4.21	4.22	4.24	4.25	4.27	4.28	4.29	4.31	4.32	4.34
42	4.13	4.14	4.16	4.17	4.19	4.20	4.22	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33
43	4.12	4.12	4.15	4.16	4.18	4.19	4.21	4.22	4.24	4.25	4.26	4.28	4.29	4.31	4.32
44	4.11	4.13	4.14	4.16	4.17	4.18	4.20	4.21	4.23	4.24	4.26	4.27	4.28	4.30	4.31
45	4.10	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.30
46	4.10	4.11	4.12	4.14	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25	4.27	4.28	4.30
47	4.09	4.10	4.12	4.13	4.14	4.16	4.17	4.19	4.20	4.22	4.23	4.24	4.26	4.27	4.29
48	4.08	4.09	4.11	4.12	4.14	4.15	4.17	4.18	4.19	4.21	4.22	4.24	4.25	4.27	4.28
49	4.07	4.09	4.10	4.11	4.13	4.14	4.16	4.17	4.19	4.20	4.21	4.23	4.24	4.26	4.27
50	4.06	4.08	4.09	4.11	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25	4.26
51	4.06	4.07	4.08	4.10	4.11	4.13	4.14	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25
52	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25
53	4.04	4.05	4.07	4.08	4.10	4.11	4.12	4.14	4.15	4.17	4.18	4.20	4.21	4.22	4.24
54	4.03	4.05	4.06	4.07	4.09	4.10	4.12	4.13	4.14	4.16	4.17	4.19	4.20	4.21	4.22
55	4.02	4.04	4.05	4.07	4.08	4.09	4.11	4.12	4.14	4.15	4.17	4.18	4.19	4.21	4.22
56	4.02	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.13	4.14	4.16	4.17	4.19	4.20	4.21
57	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.11	4.12	4.13	4.15	4.16	4.18	4.19	4.20
58	4.00	4.01	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.13	4.14	4.15	4.17	4.18	4.20
59	4.00	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15	4.16	4.17	4.19
60	3.99	4.01	4.02	4.03	4.04	4.06	4.07	4.08	4.10	4.12	4.13	4.14	4.16	4.17	4.18
61	3.98	4.00	4.01	4.02	4.04	4.06	4.07	4.08	4.10	4.11	4.12	4.14	4.15	4.16	4.17
62	3.97	3.99	4.00	4.02	4.03	4.04	4.06	4.07	4.08	4.10	4.11	4.13	4.14	4.15	4.16
63	3.97	3.98	3.99	4.00	4.02	4.04	4.05	4.06	4.08	4.09	4.11	4.12	4.14	4.15	4.16
64	3.96	3.97	3.99	4.00	4.01	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.12	4.14	4.15
65	3.95	3.96	3.98	3.99	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15
66	3.94	3.96	3.97	3.99	4.00	4.01	4.03	4.04	4.05	4.07	4.08	4.09	4.10	4.11	4.13
67	3.93	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.07	4.08	4.09	4.10	4.11	4.12
68	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.03	4.04	4.05	4.07	4.08	4.09	4.11	4.12
69	3.92	3.93	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.06	4.07	4.09	4.10	4.11

THROUGH A FUNNEL METER AT DIFFERENT AND TEMPERATURES

.......70 deg. fahr. Standard pressure........4 inches water

deg. fahr.	Barometer Reading														
	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0
	Pressure in Inches of Water														
70	3.91	3.92	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.04	4.06	4.07	4.07	4.08	4.10
71	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.05	4.05	4.07	4.09
72	3.91	3.91	3.93	3.94	3.96	3.97	3.99	4.00	4.01	4.01	4.02	4.03	4.05	4.06	4.08
73	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.02	4.03	4.05	4.06	4.08
74	3.90	3.90	3.91	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.03	4.06	4.06	4.07
75	3.88	3.90	3.90	3.92	3.93	3.95	3.96	3.97	3.98	4.00	4.02	4.03	4.03	4.04	4.06
76	3.87	3.88	3.89	3.90	3.93	3.94	3.95	3.96	3.97	4.00	4.01	4.01	4.02	4.04	4.06
77	3.86	3.88	3.89	3.90	3.92	3.93	3.95	3.96	3.97	3.99	4.01	4.01	4.03	4.04	4.06
78	3.86	3.87	3.88	3.89	3.91	3.92	3.94	3.95	3.97	3.98	3.99	4.01	4.02	4.03	4.05
79	3.85	3.86	3.88	3.89	3.90	3.92	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.04
80	3.84	3.85	3.87	3.89	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.03
81	3.84	3.85	3.86	3.88	3.89	3.90	3.91	3.93	3.94	3.96	3.98	3.99	4.00	4.01	4.02
82	3.83	3.84	3.85	3.87	3.88	3.90	3.92	3.93	3.95	3.96	3.98	3.99	4.00	4.00	4.01
83	3.82	3.84	3.85	3.86	3.88	3.89	3.90	3.91	3.93	3.94	3.96	3.97	3.98	3.99	4.00
84	3.82	3.83	3.85	3.86	3.86	3.89	3.90	3.91	3.93	3.94	3.96	3.97	3.97	3.99	4.00
85	3.81	3.82	3.84	3.85	3.86	3.88	3.88	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99
86	3.80	3.81	3.83	3.84	3.85	3.87	3.88	3.89	3.90	3.92	3.93	3.95	3.96	3.97	3.99
87	3.80	3.80	3.82	3.83	3.84	3.86	3.87	3.88	3.89	3.90	3.92	3.94	3.95	3.97	3.98
88	3.79	3.80	3.81	3.83	3.84	3.85	3.87	3.88	3.89	3.90	3.91	3.93	3.95	3.96	3.97
89	3.78	3.80	3.81	3.82	3.84	3.84	3.86	3.87	3.88	3.89	3.91	3.92	3.94	3.95	3.97
90	3.77	3.79	3.80	3.82	3.83	3.84	3.85	3.86	3.87	3.88	3.90	3.91	3.93	3.95	3.96
91	3.76	3.78	3.80	3.81	3.83	3.84	3.84	3.86	3.87	3.88	3.90	3.91	3.92	3.94	3.96
92	3.76	3.77	3.79	3.81	3.82	3.82	3.83	3.85	3.86	3.87	3.89	3.90	3.91	3.93	3.94
93	3.75	3.76	3.78	3.79	3.80	3.82	3.83	3.84	3.86	3.87	3.88	3.89	3.90	3.92	3.93
94	3.75	3.76	3.77	3.78	3.79	3.81	3.82	3.84	3.85	3.86	3.87	3.88	3.90	3.91	3.92
95	3.74	3.75	3.76	3.78	3.79	3.81	3.82	3.83	3.84	3.85	3.86	3.88	3.89	3.91	3.92
96	3.74	3.75	3.76	3.77	3.78	3.80	3.81	3.82	3.84	3.86	3.86	3.87	3.88	3.90	3.91
97	3.73	3.74	3.75	3.77	3.78	3.79	3.80	3.82	3.84	3.85	3.87	3.87	3.89	3.89	3.90
98	3.72	3.74	3.75	3.76	3.77	3.78	3.80	3.81	3.82	3.83	3.85	3.86	3.87	3.88	3.90
99	3.71	3.73	3.73	3.75	3.77	3.78	3.79	3.80	3.81	3.83	3.84	3.86	3.87	3.88	3.89
100	3.71	3.72	3.72	3.74	3.76	3.77	3.78	3.79	3.80	3.82	3.83	3.85	3.86	3.87	3.88
101	3.70	3.71	3.72	3.74	3.75	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85	3.86	3.88
102	3.69	3.70	3.71	3.73	3.74	3.75	3.76	3.78	3.79	3.81	3.82	3.83	3.84	3.85	3.87
103	3.68	3.70	3.71	3.72	3.74	3.75	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85	3.87
104	3.67	3.69	3.70	3.71	3.72	3.74	3.75	3.76	3.78	3.79	3.80	3.81	3.83	3.84	3.86
105	3.67	3.68	3.70	3.71	3.72	3.73	3.74	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85
106	3.66	3.68	3.69	3.70	3.72	3.73	3.74	3.76	3.77	3.78	3.79	3.80	3.82	3.83	3.84
107	3.66	3.68	3.68	3.70	3.71	3.72	3.73	3.75	3.76	3.78	3.79	3.80	3.81	3.83	3.84
108	3.65	3.67	3.68	3.69	3.70	3.72	3.73	3.74	3.75	3.77	3.78	3.79	3.80	3.82	3.83

Table Giving Percentages Fast (+) and Slow (−) with Correcting Factors to be Used in Testing Large Capacity Meters with the Funnel Meter. All Figures Given on the Basis of a 1½ in. Orifice Passing One Cubic Foot Per Second at a Four Inch Water Pressure Corrected for Barometer and Thermometer Changes and for Specific Gravity of Gas Used.

Fast Meters			Slow Meters		
Time Required by Meter to Register 100 Cu. Ft. in Seconds	Per Cent Fast (Funnel Meter being Standard)	Correcting Factor. Deduct Meter Reading Per Cent	Time Required by Meter to Register 100 Cu. Ft. in Seconds	Per Cent Slow (Funnel Meter being Standard)	Correcting Factor. Add to Meter Reading Per Cent
100	O. K.	none	100	O. K.	none
99	1 +	1	101	.9 −	1
98	2 +	2	102	1.9 −	2
97	3 +	3	103	2.9 −	3
96	4.1 +	4	104	3.8 −	4
95	5.2 +	5	105	4.7 −	5
94	6.3 +	6	106	5.6 −	6
93	7.5 +	7	107	6.5 −	7
92	8.6 +	8	108	7.4 −	8
91	9.8 +	9	109	8.2 −	9
90	11.1 +	10	110	9. −	10
89	12.3 +	11	111	9.9 −	11
88	13.6 +	12	112	10.7 −	12
87	14.9 +	13	113	11.5 −	13
86	16.2 +	14	114	12.2 −	14
85	17.6 +	15	115	13. −	15
84	19. +	16	116	13.7 −	16
83	20.4 +	17	117	14.5 −	17
82	21.9 +	18	118	15.2 −	18
81	23.4 +	19	119	15.9 −	19
80	25. +	20	120	16.6 −	20
79	26.5 +	21	121	17.3 −	21
78	28.1 +	22	122	18. −	22
77	29.8 +	23	123	18.6 −	23
76	31.5 +	24	124	19.3 −	24
75	33.3 +	25	125	20. −	25
74	35.1 +	26	126	20.6 −	26
73	36.9 +	27	127	21.2 −	27
72	38.8 +	28	128	21.8 −	28

Example:—If a meter passes 100 cubic feet in 80 seconds the meter is 25 per cent fast on a basis of the funnel being standard but the correcting factor being 20, to correct meter reading, deduct 20 per cent.

Recording Volume and Pressure Gauge—This type of gauge is of great assistance in measuring casinghead gas at pressure or a vacuum.

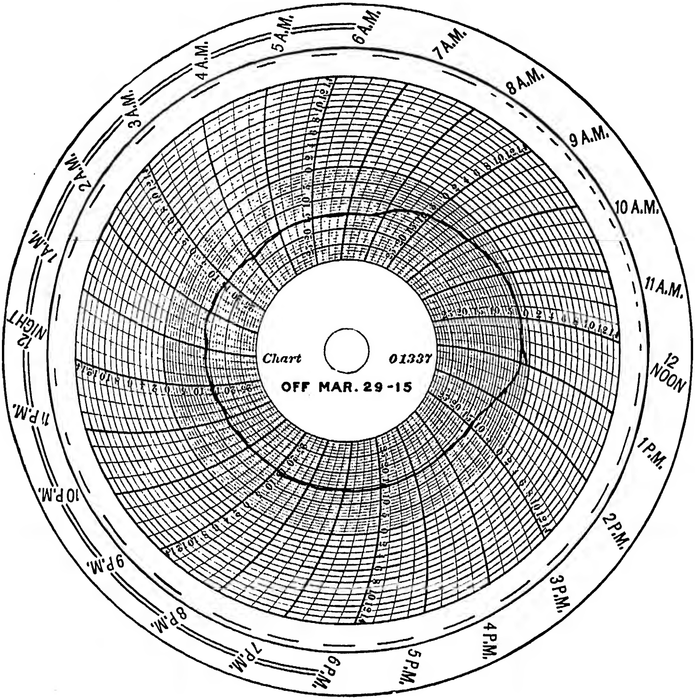


Fig. 27—RECORDING VOLUME AND PRESSURE GAUGE CHART

One great advantage in the use of a pressure and volume recording gauge when used on a large capacity meter in measuring casinghead gas is fully illustrated in Fig. 27.

In this instance the meter was installed on a six inch line leading from an oil lease to the main compressor station.

The compressor was using residue gas for fuel and during the morning of the 28th (the chart was removed on the 29th) the engineer noticed that the engine was "getting air." On visiting the nearby meters the source of trouble was soon located and remedied. It was discovered that the line on which this meter and gauge were located had been broken and the compressor was "getting air" through this meter. The pressure on the oil wells at the end of this line was about 12 inches mercury vacuum pressure when being pumped, and as the atmosphere was about 29.5 inches mercury pressure naturally this higher pressure caused the meter readings to jump up and the compressor to pump more air than it did gas at the lower pressure through this line.

As each dash on the chart indicated a volume of 10,000 cubic feet, approximately 160,000 cubic feet of air meter reading had passed the meter which without the pressure and volume recording gauge would have been paid for at five cents per thousand. With this type of gauge the gasoline company could show just when the break occurred, when it was repaired and how much meter reading should be deducted in making settlement for gas at the end of the month from that particular lease.

Density Changes in Gas Volumes at Pressures Above and Below the Atmospheric Pressure—In measuring gas at a vacuum the same formula for determining the multiplier based on Boyle's law applies as in high pressure.

To illustrate: One cubic foot of gas at four ounce pressure contains a certain number of molecules. Take a cylinder of a diameter that will contain one cubic foot for each foot in length, fitted with a tight plunger.

If the plunger in the cylinder is placed at the one foot mark and the space thus formed filled with gas to a pressure of four ounces the cylinder then holds one cubic foot at a pressure of four ounces. Now, if the plunger is moved

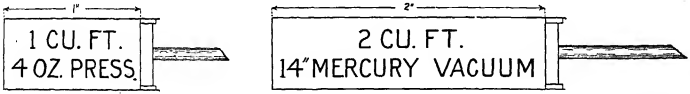


Fig. 28—PRESSURES IN CUTS ARE GAUGE PRESSURES

outward to the two foot mark the space within the cylinder would measure two cubic feet and the one cubic foot of four ounce gas would expand to fill the space while the pressure would drop to slightly greater than 14 in. of mercury vacuum pressure. To correct the two cubic feet of gas at 14 in. mercury of vacuum to a four ounce basis, multiply the two cubic feet by the multiplier for 14 in. mercury vacuum or approximately .5 as found in the four ounce multiplier table on page 117, and the result will be one cubic foot of four ounce gas.

As all gas meters in the factory are proved and corrected to a low pressure basis, measuring gas by displacement, they may be compared to the cylinder and the plunger as illustrated above.

In measuring gas in the meter, the diaphragms contain just so much space. If the pressure of the gas contained in each quantity or volume of gas measured by the diaphragm filling and discharging is four ounce, then the meter reading needs no correction; but each time the meter diaphragm fills and discharges a volume of gas at a pressure higher or lower than four ounces, the meter reading must be corrected by applying a multiplier, to reduce the volume of gas measured to a four ounce basis; and the higher the pressure the greater will be the density of the gas and the lower the pressure below the four ounce base the less the density of the gas, and the greater or less the number of the atoms contained in each cubic foot of space.

The multipliers for density are based on Boyle's law written in 1660, that the "volume of a gas varies inversely as the pressure."

While the four ounce basis is generally accepted when no other pressure basis is stated in buying and selling agreement, some other basis can be used and very often is used, particularly when gas is bought or sold in large volumes in the field.

Formula for Determining the Quantity of Natural Gas When Measured Above or Below Normal Pressure—In which

For pressure above atmospheric pressure	For pressure below atmospheric pressure
$Q=q\dfrac{p+h}{h+.25}$	$Q=q\dfrac{h-p}{h+.25}$

Q = cubic feet required.
q = cubic feet shown by the meter.
p = gauge pressure in pounds.
h = atmospheric pressure of 14.4 pounds.
0.25 = 4 ounce pressure reduced to pounds.

By substituting the known values in the above it becomes

$$Q=q\frac{p+14.4}{14.65} \quad \text{or} \quad Q=q\frac{14.4-p}{14.65}$$

Example:

As 1 lb. = .4908 inches of mercury, to determine the multiplier for 10 in. vacuum pressure, then the formula becomes:

$$Q=\frac{14.4-4.908}{14.65} = .64790 \text{ multiplier for 10 in. vacuum pressure.}$$

Multipliers for Reducing Gas Volumes or Meter Readings to Different Pressure Bases

Inches of Mercury Vacuum	2 oz.	4 oz.	8 oz.	10 oz.	1 lb.
GAUGE PRESSURE	Multiplier or Density	Multiplier or Density	Multiplier or Density	Multiplier or Density	Multiplier or Density
—28	.04527	.04488	.04413	.04376	.04270
—27	.07906	.07838	.07707	.07643	.07457
—26	.11285	.11188	.11031	.10909	.10644
—25	.14660	.14535	.14291	.14172	.13827
—24	.18039	.17885	.17585	.17439	.17014
—23	.21418	.21236	.20879	.20706	.20201
—22	.24798	.24586	.24173	.23972	.23389
—21	.28177	.27936	.27468	.27239	.26576
—20	.31556	.31287	.30762	.30506	.29763
—19	.34935	.34637	.34056	.33772	.32950
—18	.38314	.37987	.37350	.37039	.36137
—17	.41693	.41338	.40644	.40306	.39324
—16	.45073	.44688	.43938	.43573	.42512
—15	.48452	.48038	.47232	.46839	.45799
—14	.51831	.51389	.50526	.50106	.48880
—13	.55210	.54739	.53820	.53373	.52073
—12	.58590	.58090	.57115	.56639	.55260
—11	.61970	.61440	.60409	.59906	.58447
—10	.65348	.64790	.63703	.63173	.61634
— 9	.68727	.68141	.66997	.66439	.64822
— 8	.72107	.71491	.70291	.69706	.68009
— 7	.75485	.74841	.73585	.72973	.71196
— 6	.78865	.78191	.76879	.76240	.74383
— 5	.82244	.81542	.80173	.79506	.77570
— 4	.85623	.84892	.83467	.82773	.80757
— 3	.89002	.88242	.86761	.86040	.83945
— 2	.92381	.91593	.90056	.89306	.87132
— 1	.95760	.94943	.93350	.92573	.90319
Atmos.	.99139	.98293	.96644	.95840	.93506
Lb. per Sq. In.					
.125	1.00000	.99146	.97483	.96672	.94318
.25	1.00860	1.00000	.98322	.97504	.95129
.5	1.02581	1.01706	1.00000	.99168	.96753

Multipliers for Reducing Gas Volumes or Meter Reading

to Different Pressure Bases

Inches of Mercury Vacuum / Gauge Pressure Lb. per Sq. In.	2 oz. Mulitplier or Density	4 oz. Multiplier or Density	8 oz. Multiplier or Density	10 oz. Multiplier or Density	1 lb. Multiplie or Density
.625	1.03442	1.02559	1.00838	1.00000	.97564
1	1.06024	1.05119	1.03355	1.02495	1.00000
1.5	1.09466	1.08532	1.06711	1.05823	1.03246
2	1.12908	1.11945	1.10067	1.09151	1.06493
2.5	1.16351	1.15358	1.13422	1.12479	1.09740
3	1.19793	1.18771	1.16778	1.15806	1.12987
3.5	1.23235	1.22184	1.20134	1.19134	1.16233
4	1.26678	1.25597	1.23489	1.22462	1.19480
4.5	1.30120	1.29010	1.26845	1.25790	1.22727
5	1.33562	1.32423	1.30201	1.29118	1.25974
5.5	1.37005	1.35836	1.33557	1.32445	1.29220
6	1.40447	1.39249	1.36912	1.35773	1.32467
6.5	1.43889	1.42662	1.40268	1.39101	1.35714
7	1.47332	1.46075	1.43624	1.42429	1.38961
7.5	1.50774	1.49488	1.46979	1.45757	1.42207
8	1.54216	1.52901	1.50335	1.49084	1.45454
8.5	1.57659	1.56313	1.53691	1.52412	1.48701
9	1.61101	1.59726	1.57046	1.55740	1.51948
9.5	1.64543	1.63139	1.60402	1.59068	1.55194
10	1.67986	1.66552	1.63758	1.62396	1.58441
10.5	1.71428	1.69965	1.67114	1.65723	1.61688
11	1.74870	1.73378	1.70469	1.69051	1.64935
11.5	1.78313	1.76791	1.73825	1.72379	1.68181
12	1.81755	1.80204	1.77181	1.75707	1.71428
12.5	1.85197	1.83617	1.80536	1.79034	1.74675
13	1.88640	1.87030	1.83892	1.82362	1.77922
13.5	1.92082	1.90443	1.87248	1.85690	1.81168
14	1.95524	1.93856	1.90604	1.89018	1.84415
14.5	1.98967	1.97269	1.93959	1.92346	1.87662
15	2.02409	2.00682	1.97315	1.95673	1.90909
16	2.09294	2.07508	2.04026	2.02329	1.97402
17	2.16178	2.14334	2.10738	2.08985	2.03896
18	2.23063	2.21160	2.17449	2.15640	2.10389
19	2.29948	2.27986	2.24161	2.22296	2.16883
20	2.36833	2.34812	2.30872	2.28951	2.23376

Multipliers for Reducing Gas Volumes or Meter Readings to Different Pressure Bases

Inches of Mercury Vacuum	2 oz.	4 oz.	8 oz.	10 oz.	1 lb.
Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Multiplier or Density	Multiplier or Density	Multiplier or Density	Multiplier or Density
21	2.43717	2.41638	2.37583	2.35607	2.29870
22	2.50602	2.48464	2.44295	2.42262	2.36363
23	2.57487	2.55290	2.51006	2.48918	2.42857
24	2.64371	2.62116	2.57718	2.55574	2.49350
25	2.71256	2.68941	2.64429	2.62229	2.55844
26	2.78141	2.75767	2.71140	2.68885	2.62337
27	2.85025	2.82593	2.77852	2.75540	2.68831
28	2.91910	2.89419	2.84563	2.82196	2.75324
29	2.98795	2.96245	2.91275	2.88851	2.81818
30	3.05679	3.03071	2.97986	2.95507	2.88311
31	3.12564	3.09879	3.04697	3.02163	2.94805
32	3.19449	3.16723	3.11409	3.08818	3.01298
33	3.26333	3.23549	3.18120	3.15474	3.07792
34	3.33218	3.30375	3.24832	3.22129	3.14285
35	3.40103	3.37201	3.31543	3.28785	3.20779
36	3.46987	3.44027	3.38255	3.35440	3.27272
37	3.53872	3.50853	3.44966	3.42096	3.33766
38	3.60757	3.57679	3.51677	3.48752	3.40259
39	3.67641	3.64505	3.58389	3.55407	3.46753
40	3.74526	3.71331	3.65100	3,62063	3.53246
41	3.81411	3.78156	3.71812	3.68718	3.59740
42	3.88296	3.84982	3.78523	3.75374	3.66233
43	3.95180	3.91808	3.85234	3.82029	3.72727
44	4.02065	3.98634	3.91946	3.88685	3.79220
45	4.08950	4.05460	3.98657	3.95341	3.85714
46	4.15834	4.12286	4.05369	4.01996	3.92207
47	4.22719	4.19112	4.12080	4.08652	3.98701
48	4.29604	4.25938	4.18791	4.15307	4.05194
49	4.36488	4.32764	4.25503	4.21963	4.11688
50	4.43373	4.39590	4.32214	4.28618	4.18181

Siphon or "U" Gauges—These are the most convenient low pressure gauges in use, being portable and simply screwed to the piping wherever it is desired to take the pressure.

They consist of a U-shaped glass tube with a metal goose-neck, in sizes from 4 inch to 36 inch. Between the two sides or legs of this tube is set a scale graduated in inches and tenths, or pounds and ounces, as desired. A bent brass tube, or goose-neck, is connected to the "U" tube at the top and runs down the side to the gas connection.

When used the gauge is filled with water or mercury to the center of the scale, which is zero. The gauge is connected to the gas supply and the pressure turned on. The liquid will fall below zero on the inlet side of the "U" tube and rise on the opposite side the same distance. The distance between the two levels of the liquid as shown by the scale will give the amount of pressure in inches and tenths or in pounds and ounces, according to the graduation.

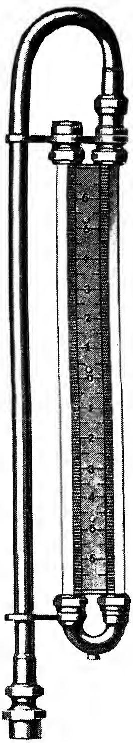


Fig. 29—SIPHON OR "U" GAUGE

While the gauge is in use the downward motion of the liquid in one column, due to the pressure of the gas, should equal the rise of liquid in the opposite column. In case the water, after being set at zero, should not drop on the pressure side as much as it rises on the other side, it is an indication that the glass tubes are not of equal diameter, and both columns must be read, their sum being the true pressure.

Water is generally used in siphon gauges in testing domestic meters and measuring small gas wells. It is also used in testing large capacity meters in the field.

The Equivalents of Ounces, per Square Inch, in Inches of Height of Columns of Water and Mercury

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
0.146	0.25	0.018	7	12.11	0.892
0.292	0.51	0.037	8	13.85	1.019
0.438	0.76	0.055	9	15.58	1.146
0.584	1.01	0.074	10	17.31	1.277
1	1.73	0.127	11	19.05	1.401
2	3.46	0.255	12	20.78	1.528
3	5.19	0.382	13	22.51	1.655
4	6.92	0.510	14	24.24	1.783
5	8.65	0.637	15	25.97	1.910
6	10.38	0.765	16	27.71	2.037

27.71 inches of water and 2.0374 inches of mercury equal one pound per square inch at atmospheric pressure and 62 deg. fahr. temperature. Mercury is 13.59 times as heavy as water.

PART SIX

Gasoline Plants—Compression Method

Gasoline plants vary in size from single well plants compressing from 3 to 5,000 cubic feet of casinghead gas per day and making as small as fifty gallons of gasoline per day to plants with six and eight compressors compressing several million cubic feet of gas daily making from twenty to thirty thousand gallons of gasoline.

In the former a fifteen h. p. gas engine is used which in addition to furnishing power to run a vacuum pump and a single stage compressor, also furnishes power to the walking beam for pumping oil.

The compressor generally used is a 6 by 6 size running about 100 rev. per min., while the vacuum pump is a Duplex type with much larger cylinders and running about 40 rev. per min. The gas is compressed to about 80 lb. pressure while the vacuum maintained on the oil sand is about 18 to 19 inches vacuum.

At several plants in the Sistersville, W. Va., district the gas is very rich, showing on test as high as 13 gallons of gasoline per thousand cubic feet of gas, consequently, after the extraction of gasoline there is too small a quantity of residue gas left to run the gas engine, compelling the purchase of natural gas from the local gas company.

The gasoline extracted is of 86 deg. to 90 deg. Baume. It is collected in iron drums and hauled by wagon to a nearby market.

Generally one man has charge of three or four plants which are run twenty-four hours daily same as with large installations.

Some of the larger plants in Oklahoma are as complete in every detail and cost as much to install as many of the

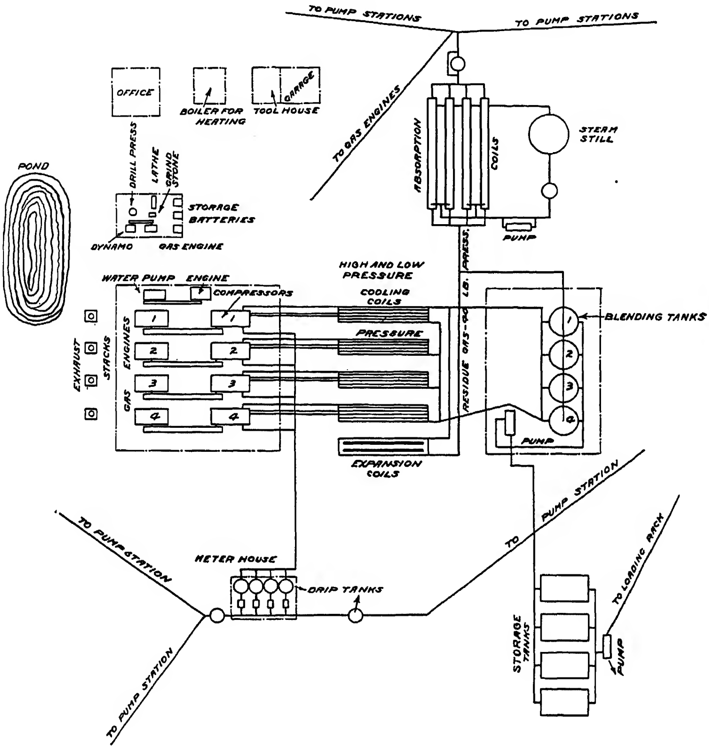


Fig. 30—GENERAL PLAN OF GASOLINE PLANT. COMPRESSOR SYSTEM

large gas compressing stations operated by the large natural gas companies.

In addition to compressors, cooling coils, tanks and gas engines their equipment included a complete electric lighting system with storage batteries, lathes, drill presses, grinders, overhead crane, a complete water system under fire pressure, a chemical cart for extinguishing fires, private telephone and telegraph lines to main office and to booster

stations, a well equipped steam heating system for entire plant, a suitable office, garage and employees' houses.

The completeness and attractive appearance of many plants visited by the author are a credit to their owners. In one instance the meter installation was more complete in every detail and kept in better condition than any similar installation the author has ever seen on a natural gas line.

In the Sistersville district the casinghead gas is compressed to from 80 lb. to 100 lb. and the discharge lines from the compressor lead through tanks containing running water. The coldest water is at the outlet of the coil from the tank.

In the Oklahoma field the casinghead gas is compressed as high as 225 to 275 lb. and the compressed gas is conducted through a series of coils which are cooled by constantly dripping water.

As the compressed gas passes through the cooling coils under high pressure the hydrocarbons or gasoline condense and are trapped at the discharge end of the coils from which point they are pumped into blending tanks where the gravity is attained by blending with naphtha. After blending it is ready for the market.

It is more profitable to make the lower gravity gasoline (even though less of it is obtained from 1,000 cubic feet of gas) than it is to install expensive machinery and extract a greater number of gallons of high gravity gasoline, because the latter is so volatile that one is able to market but a fraction of the quantity actually made.

Construction of Gasoline Plant—If the range of pressures through which the gas is to be compressed exceeds seven or eight compressions, it is necessary to use a two-stage compressor in order to keep the temperature within proper working limits. For this class of work a single two-stage unit, with an intercooler forming a part of it, is satisfactory.

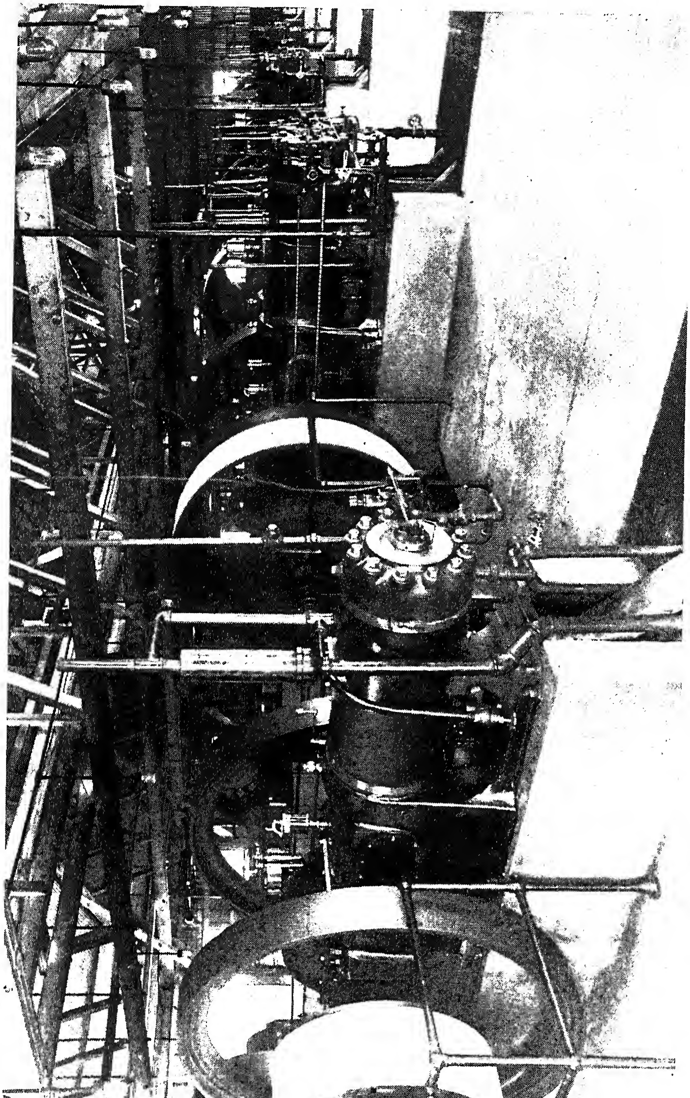


Fig. 31—INTERIOR OF COMPRESSOR PLANT

TABLE OF INDICATED HORSE POWER ON THE COMPRESSOR PISTON PER MILLION CUBIC FEET OF GAS PER DAY

Suction Pressure	Discharge Pressure, Pounds, per Square Inch, Gauge													
	50		60		70		80		90		100		125	
	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage
10 In. Vac.	111.3	107.0	123.0	114.0	133.7	121.6	144.3	128.2	......	133.8	......	139.0	......	150.0
5	96.0	95.8	105.7	103.0	115.1	110.5	124.0	116.0	132.8	121.0	141.3	126.2	......	137.8
0 Lb.	84.3	......	93.8	93.8	102.0	100.0	110.0	106.0	117.5	111.2	125.0	116.0	142.7	127.4
5	67.0	......	75.3	......	82.8	......	89.5	......	96.0	95.8	102.2	100.2	116.8	110.2
10	54.5	......	62.5	......	69.5	......	75.9	......	81.8	......	88.8	......	100.0	98.2
15	44.6	......	52.5	......	59.0	......	65.4	......	71.0	......	76.3	......	88.0	......
20	......	......	44.0	......	50.8	......	56.9	......	62.3	......	67.4	......	78.6	......
25	......	......	......	......	43.8	......	49.5	......	54.8	......	59.6	......	71.0	......
30	......	......	......	......	......	......	43.4	......	48.7	......	53.2	......	64.1	......
35	......	......	......	......	......	......	......	......	42.9	......	48.0	......	58.1	......
40	......	......	......	......	......	......	......	......	......	......	42.5	......	53.0	......
45	......	......	......	......	......	......	......	......	......	......	......	......	48.5	......
50	......	......	......	......	......	......	......	......	......	......	......	......	44.0	......
60	......	......	......	......	......	......	......	......	......	......	......	......	......	......
70	......	......	......	......	......	......	......	......	......	......	......	......	......	......
80	......	......	......	......	......	......	......	......	......	......	......	......	......	......
90	......	......	......	......	......	......	......	......	......	......	......	......	......	......
100	......	......	......	......	......	......	......	......	......	......	......	......	......	......
120	......	......	......	......	......	......	......	......	......	......	......	......	......	......
140	......	......	......	......	......	......	......	......	......	......	......	......	......	......
160	......	......	......	......	......	......	......	......	......	......	......	......	......	......
180	......	......	......	......	......	......	......	......	......	......	......	......	......	......
200	......	......	......	......	......	......	......	......	......	......	......	......	......	......

TABLE OF INDICATED HORSE POWER ON THE COMPRESSOR PISTON PER MILLION CUBIC FEET OF NATURAL GAS PER DAY—Continued

Suction Pressure	Discharge Pressure, Pounds per Square Inch, Gauge													
	150		175		200		225		250		275		300	
	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage
10 In. Vac.	......	159.6	......	168.0	......	176.0	......	182.2	......	189.0	......	194.6	......	200.0
5	......	146.4	......	154.6	......	162.2	......	168.6	......	175.0	......	180.2	......	185.8
0 Lb.	......	136.2	......	144.6	......	151.4	......	158.0	......	164.0	......	169.0	......	174.2
5	130.3	120.0	143.5	127.8	......	134.5	......	141.0	......	146.0	......	151.6	......	156.6
10	112.0	107.6	123.0	114.6	133.8	122.0	144.1	128.0	......	133.6	......	138.6	......	143.4
15	98.5	97.6	108.3	105.6	118.0	111.6	126.9	117.4	135.8	123.0	144.4	128.2	......	132.6
20	88.3	......	97.5	97.0	106.0	103.4	114.2	109.4	122.1	114.0	129.9	119.4	137.4	124.0
25	80.1	......	88.8	......	96.8	96.0	104.2	102.0	111.4	107.2	118.5	112.0	125.2	116.2
30	73.3	......	81.7	......	89.1	......	96.1	95.6	103.0	100.6	109.4	106.0	115.8	110.0
35	67.3	......	75.1	......	82.5	......	89.3	......	95.8	95.4	101.7	100.0	107.7	104.4
40	62.0	......	69.9	......	76.9	......	83.3	......	89.4	......	95.2	94.8	100.7	99.0
45	57.0	......	65.0	......	71.8	......	78.2	......	84.2	......	89.7	......	95.0	94.6
50	52.9	......	60.5	......	67.3	......	73.5	......	79.1	......	84.7	......	89.7	......
60	45.1	......	52.9	......	59.1	......	65.3	......	71.1	......	76.2	......	81.0	......
70	......	......	45.9	......	52.8	......	58.2	......	64.0	......	69.1	......	73.6	......
80	......	......	40.2	......	46.5	......	52.8	......	57.7	......	62.8	......	67.3	......
90	......	......	......	......	41.5	......	47.0	......	52.5	......	57.0	......	62.0	......
100	......	......	......	......	......	......	42.1	......	47.5	......	52.7	......	56.9	......
120	......	......	......	......	......	......	......	......	......	......	43.9	......	48.4	......
140	......	......	......	......	......	......	......	......	......	......	......	......	41.0	......
160	......	......	......	......	......	......	......	......	......	......	......	......	......	......
180	......	......	......	......	......	......	......	......	......	......	......	......	......	......
200	......	......	......	......	......	......	......	......	......	......	......	......	......	......

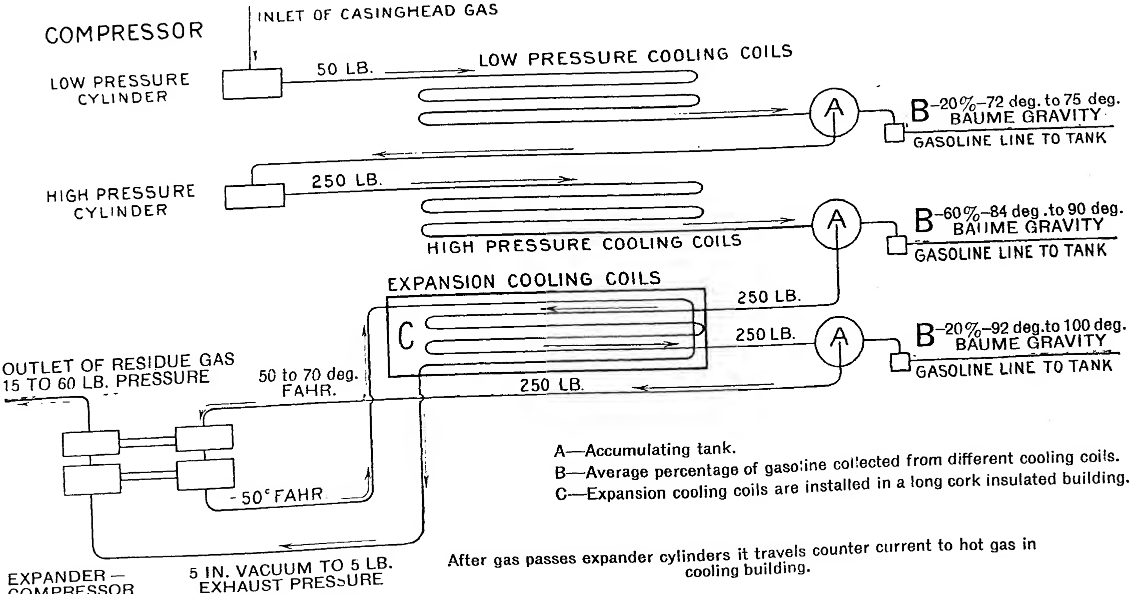


Fig. 32—DIAGRAM OF A COMPRESSOR, COOLING COIL, ACCUMULATING TANKS AND EXPANDER. Showing Pressures and Average Percentage of Gasoline Collected at Each Collecting Point

low pressure expanding cylinder and is expanded in the low pressure cylinder to the neighborhood of five pounds pressure, and sometimes to as low as five inches vacuum at the exhaust outlet. The expansion of the gas is regulated by hand cut-off valves on both the high and low pressure cylinders. The expanded gas, due to its low temperature, is used for the further cooling of the casinghead gas after it leaves the high pressure water cooled coils and accumulator tanks. The expanded gas leaves the exhaust of the expander at a temperature of from 40 to 60 degrees below zero fahr. and passes through a set of double pipe coils counter current to the travel of the casinghead gas. These coils are generally inclosed in a long narrow cork insulated house. After the cooling gas has passed through the double pipe coils it passes on to the intake of the duplex single stage or two stage compressor, as the case might be, and is discharged by the compressor into the field return line, where the gas is used for fuel.

The amount of gasoline that can be extracted from casinghead gas by the use of an expander-compressor depends entirely on the efficiency of the water cooled coils. With proper designed water cooled coils and sufficient cooling water the expander-compressor generally adds from six to ten per cent of the gasoline yield. While with poorly designed and inefficient water cooled coils, due to scarcity of cooling water, or other causes, the expander-compressor in some cases, has increased the yield of the gasoline as high as twenty per cent.

Owing to the extreme low temperatures within the cylinder walls of the expansion cylinders it has been found quite difficult to properly lubricate the valves in cylinders; in fact, the only dependable lubricant so far found is glycerine.

In some cases the compressor end of the expander-compressor is used to compress casinghead gas instead of compressing the dry gas for its return to the field. When the compressor end of the expander is used for compressing casinghead gas it is then necessary to use auxiliary machinery to discharge the dry gas to the field for fuel.

See diagram, Fig. 32 on page 130 and illustration, Fig. 33 on page 132.

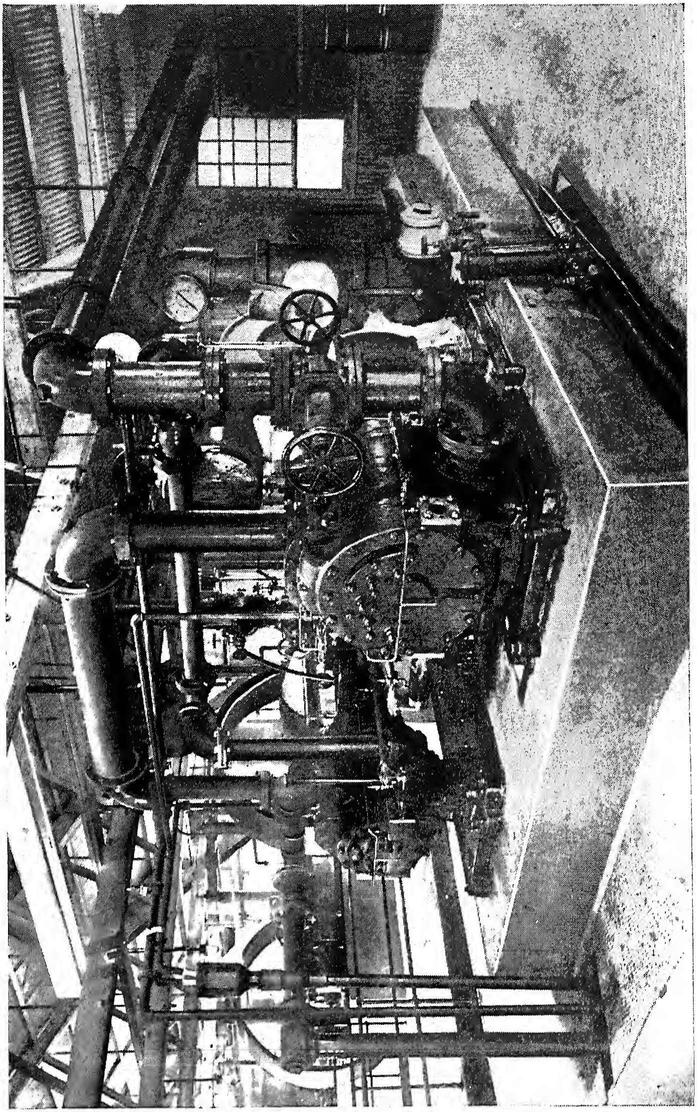


Fig. 33—AN EXPANDER USED TO INCREASE THE YIELD OF GASOLINE EXTRACTED FROM CASINGHEAD GAS.
Expander is Installed on Gas Lines After Gas Leaves the Cooling Coils

Condensing Pressures—While the higher the pressure of the casinghead gas the greater the amount of the gasoline obtained through proper cooling agents, it is not profitable to subject the casinghead gas to a greater pressure than three hundred pounds. Many gasoline plants operate at pressures that do not exceed 100 lbs. The reason for this is that the gasoline obtained at high pressure is of such high gravity that after it is condensed it is very difficult to keep the condensate in the liquid form. A large percentage of the higher gravity gasoline after entering the accumulator tanks re-evaporates and passes off in the residue gas which accounts for the residue gas being richer than most natural gas in heating value.

Compression and Liquefication of the Constituents of Casinghead Gas in Plant Operation—The condensation of gasoline from natural gas is essentially a physical process. If any chemical reactions take place, they are slight, and inappreciable. G. A. Burrell tested residual gases from 10 different plant operations to determine whether carbon monoxide or olefin hydrocarbons were produced. These gases with others are found when the higher paraffins are decomposed at high temperatures and pressures in the absence of air. Neither carbon monoxide nor olefin hydrocarbons were found.

Percentage of Vapor Condensed by Compression and Cooling (from Bulletin 88, Bureau of Mines)—"The change in the raw gas that takes place in the compressors and coolers of a plant consists in the conversion of certain vapors and gases into liquid condition, and the solution of gases in these liquids. To give exact figures for the proportions of gas and vapor that disappear is impossible. An approximation, however, can be reached. One gallon of liquid propane when converted into gas produces about 31 cubic feet of gas at 0° cent. and 760 mm. pressure. One gallon of propane in the liquid condition produces about 45 cubic feet of

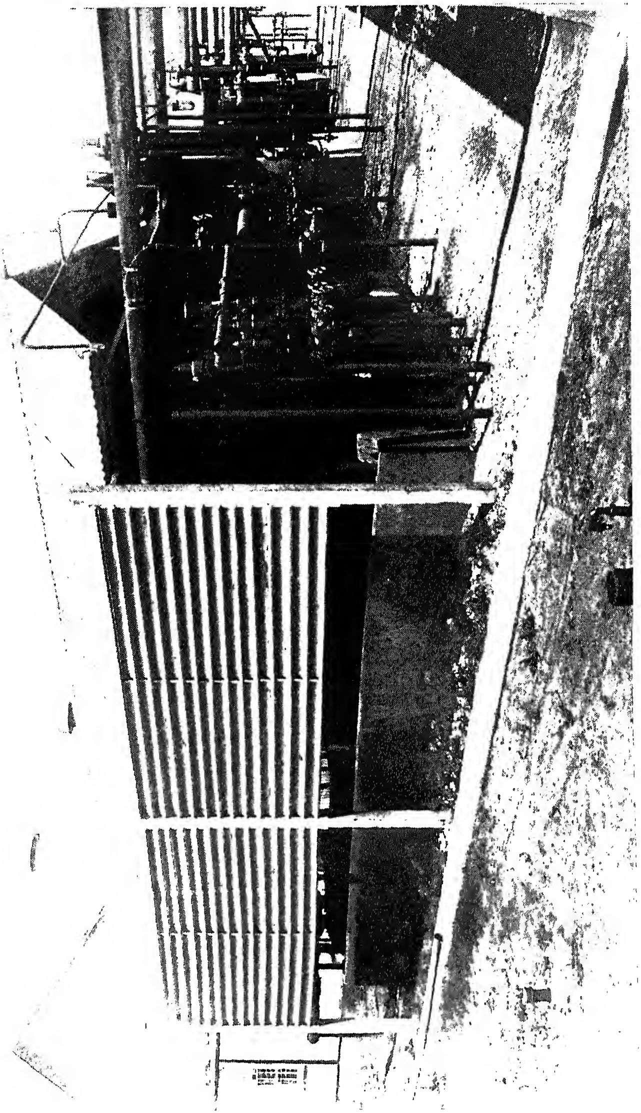


Fig. 34—COOLING COILS

gas. One gallon of butane produces 37 cubic feet of gas. Butane and pentane are probably the two paraffins that are removed in greatest quantity.

Aside from such liquefaction a certain amount of gas is absorbed by the liquid, as stated above. It is small as compared to the total disappearance of gas. The authors estimate that at some plants about 35 cubic feet of gas disappears for each gallon of condensate produced from 1,000 cubic feet of gas. If 4 gallons of condensate per 1,000 cubic feet of gas is obtained, then 140 cubic feet, or about 14 per cent of the gas treated, has disappeared. At some plants, however, as much as 50 per cent of gas disappears, and at others the quantity of residual gas is almost insignificant."

Lighting Plant—While there is danger of explosion due to the breaking of an incandescent light bulb in an explosive mixture of gas and air, nevertheless the electric light furnishes the least dangerous method of lighting a gasoline-gas plant and should invariably be used. Good ventilation should always be provided to prevent the accumulation of gas, and all light bulbs should be guarded to prevent breakage.

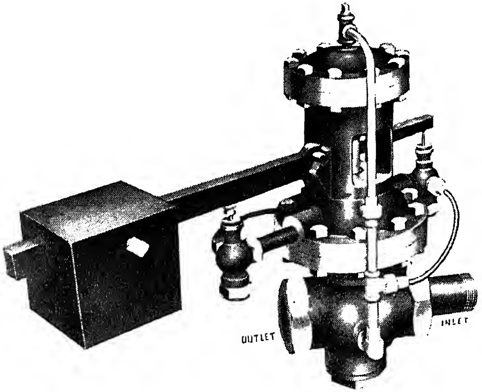


Fig. 35 GAS RELIEF VALVE OR REGULATOR FOR GASOLINE PLANTS

Gas Relief Regulator—This regulator is of special interest to gasoline makers.

After the gasoline has been compressed to a high pressure, generally about three hundred pounds, per square inch, this type of regulator will reduce the pressure to twenty or thirty pounds and retain that pressure. If the pressure ahead of the regulator drops below that at which it is set, it will cut off. In other words it acts the opposite of a standard regulator used in distributing gas.

Results of Analyses of Gases from Different Stages of Plant Operation—(George A. Burrell.)—"Table following shows the results of laboratory tests of various gases derived from the different stages of plant operation. The percentage of air was calculated from the oxygen content as determined by analysis.

Regarding the results shown in table on page 137, the chemical analysis, the specific gravity determination, and the claroline oil absorption show the gas represented to be a rich one. It will be seen that little difference existed between the composition of the crude gas and the same gas after it had been compressed to a pressure of 50 pounds per square inch. Only after the compression to a pressure of 250 pounds per square inch and cooling, did the composition of the gas mixture change appreciably.

Under existing methods of plant operation, condensate is extracted from natural gas that ranges in specific gravity from as low as 0.8 to as high as 1.65 (air=1) and the solubilities of the gas in claroline oil ranges from 36.9 (air free) to 85.7 per cent, according to the well from which it comes.

The authors hesitate to recommend the installation of a plant to handle natural gas that shows results as poor as the minimum values given in the table. Such gas might produce gasoline in paying quantities and might not. Probably the safest extremes would be a specific gravity of 0.85

RESULTS OF LABORATORY TESTS OF SAMPLES OF GAS FROM DIFFERENT GASOLINE PLANTS

(Bureau of Mines—Paper No. 88). PLANT NEAR FOLLANSBEE, W. VA.

Condition of gas	Cal. gross heating value per cu. ft. at 0°C. and 760 mm.	Special Gravity at 0°C. and 760 mm. (air = 1.)	Proportion absorbed by 25 cc. of oil.	Composition								Remarks
				Air	CH_4	C_2H_6	C_3H_8	C_4H_{10}	N_2	CO_2	Total	
	B.t.u.			per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	
Natural gas as drawn from the well	2,544	1.46	85.7	......	......	10.8	88.3	......	0.9	.....	100	The gas was drawn from 75 producing oil wells, under a reduced pressure of 20 inches of mercury.
Residual gas after removal of 50 pounds of compression product.	2,515	1.46	......	......	......	16.9	82.9	......	0.2	.....	100	The gasoline produced was shipped in drums to Pittsburgh, Pa., where
Residual gas after removal of 250 pounds of compression product.	2,171	1.23	78.2	......	......	59.2	40.3	......	0.5	.....	100	it was blended with refinery naphtha for the market.
Natural gas as drawn from the well	2,474	1.41	83.6	......	......	21.4	78.2	......	.4	.....	100	These samples were taken from the same plant as
Residual gas after removal of 50 pounds of compression product.	2,415	1.38	82.0	......	......	26.5	72.4	......	1.1	.....	100	those above, but were taken two months previous.
Residual gas after removal of 250 pounds of compression product.	2,022	1.15	63.6	......	......	77.3	22.0	......	.7	.....	100	

NOTE—This table does not apply to residue gas but to casinghead gas direct from wells.

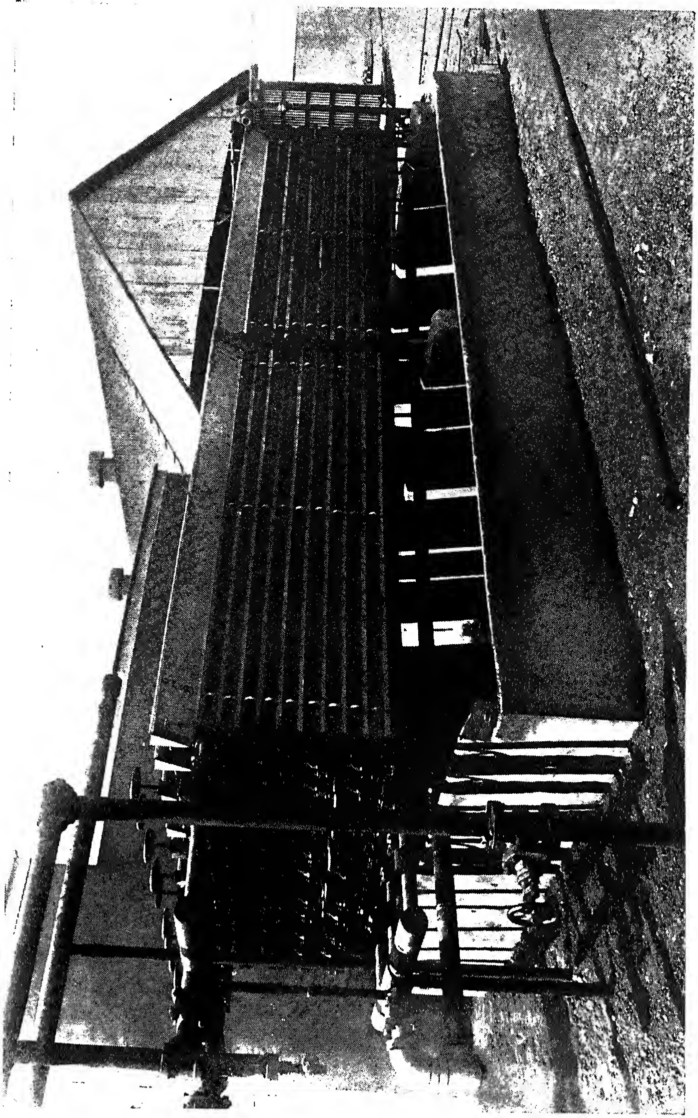


Fig. 36—COOLING COIL. Showing Water Pit Before Roof and Sun Screen Have Been Installed

(air=1), and a claroline-oil absorption of 35 per cent. The natural gas supplied to Pittsburgh, Pa., with which the authors are most familiar, contains little of the gaseous hydrocarbons, has a specific gravity of 0.64 (air=1), and has a claroline-oil absorption of about 16 per cent. It is a dry gas and is unsuitable for gasoline production by the compression method.

Description of Ordinary Ammonia Refrigerating Machine (from Bulletin 88, Bureau of Mines)—"An ordinary ammonia refrigerating machine, such as is used for cooling purposes, in general consists essentially of three parts—a refrigerator or evaporator, a compression pump and a condenser.

The refrigerator, which consists of a coil or a series of coils, is connected to the suction side of the pump, and the delivery from the pump is connected to the condenser, which is generally of a somewhat similar construction to the refrigerator. The condenser and the refrigerator are joined by a pipe in which is a valve called the regulator. Outside the refrigerating coils is the air, brine, or other substance that is to be cooled in the refrigeration system; and outside the condenser is the cooling medium, which is water. The liquid ammonia passes from the bottom of the condenser through the regulating valve into the refrigerator in a continuous stream. As the pressure in the refrigerator is reduced by the pump and maintained at such a degree as to give the desired boiling point—which is, of course, always lower than the temperature outside the coils—heat passes from the substance outside through the coil surfaces and is taken up by the entering liquid, which is converted into vapor. The vapors thus generated are drawn into the pump, compressed, and discharged into the condenser, the temperature of which is somewhat above that of the cooling water. Heat is transferred from the compressed vapor to the cooling water, and the vapor is converted into a liquid which collects at the

bottom and returns by the regulating valve into the refrigerator. The compressor may be driven by a gas engine or in any other convenient manner. The pressure in the condenser varies according to the temperature of the cooling water, and that in the refrigerator is dependent upon the temperature to which the outside substance is cooled.

Anhydrous ammonia is a gas at ordinary temperatures and under atmospheric temperatures. The liquid anhydrous ammonia is commercially sold in iron drums in which it is contained under a pressure varying between 120 and 200 pounds per square inch, the pressure in the drum depending on the temperature of the liquid in it.

Some idea of the nature of the natural gas condensate obtained can be had by considering the liquefaction points of the constituents that are found in natural gases used for gasoline condensation. The boiling point of liquid propane is — 45 deg. cent. (—49 deg. fahr.), and of liquid butane 1 deg. cent. (34 deg. fahr.)

The lowest temperature obtained in the refrigerating coils of the Olinda plant is — 10 deg. cent. (14 deg. fahr.) Hence it can be accepted that no propane is liquefied, but some butane and higher paraffins are. The efficiency of the extraction of the condensible constituents from the natural gas for any given temperature will depend upon the velocity of the gas through the coils, or, what is the same thing, the area of cooling surface. Heat is of course extracted from the natural gas when it enters the cooling system. If the cooling area of the pipes is not great enough, the residual natural gas will leave the system still containing gasoline vapors that could have been condensed by further cooling treatment. By proper experimentation the amount of cooling surface required to produce the greatest quantity of salable condensate can be ascertained. Presumably the operators of the Olinda plant have made such a determination. They

believe that the refrigeration method offers much promise and that more plants of this type will be installed.

In the United States at least 85 per cent of the refrigeration plants used for various purposes use ammonia as the refrigerant. Other refrigerants that may be used are sulphur dioxide, carbon dioxide, and water vapor."

Horse Power of Gas Engines—The horse power of a gas engine is usually rated as the actual power delivered to the belt on average fuel. This power delivered to the belt bears a close relationship to the power developed in the cylinder and the more excellent the design and construction of the engine the more nearly will these two powers be equal.

Power is developed by compressing a mixed charge of gas and air in the cylinder and then igniting it. The heat produced by the combustion causes the gases to expand and exert a pressure on the piston which drives the latter forward to the end of its stroke when the pressure is released by means of the exhaust valve.

The pressure due to rapid combustion is the same for any size engine provided the compression and mixture are the same and the horse power of the engine depends upon the size of the cylinder.

Various ratings are used to designate the size of an engine, but the surest guide to comparative power is to compare the sizes of cylinders.

Size for size a two cycle engine will develop something less than twice the power of a four cycle engine.

In buying engines, do not be guided altogether by horse power rating, but look well into cylinder sizes to determine whether the engine is large enough to justify its rating.

Length and Diameter of Services for Small Gas Engines

Horse Power of Engine	50 Feet of Pipe Diam. In.	100 Feet of Pipe Diam. In.	150 Feet of Pipe Diam. In.	225 Feet of Pipe Diam. In.
5	1	1	1¼	1¼
10	1¼	1½	1½	1½
15	1¼	2	2	2
20	1½	2	2	2
30	1½	2½	2½	2½
40	2	2½	2½	3
50	2½	2½	3	3

Multiply the horse power of the engine by 0.03 and add three quarters of one inch to find the proper size of gas supply pipe.

Exhaust Pipe—The exhaust pipe should be as straight and free from bends as possible and the outlet also should be shielded to prevent rain collecting therein. The diameter of the exhaust pipe should be between one third and one quarter of the cylinder diameter.

Circulating Water—Water must be kept circulating in the jacket of the engine cylinder to cool the walls and make lubrication possible. This requires from four to six gallons per horse power per hour. Where a tank is used its capacity should be such as to allow twenty to forty gallons per horse power.

The water circulating pipes should be free from bends and the top or return pipe should be one half inch larger than the bottom or inlet pipe. The return pipe should enter the tank below the top level of the water therein.

When hard water is used for the jacket put a handful of ordinary washing soda into the tank about once a month.

Circulating water should first be pumped through the compressor cylinder jacket, then through the gas engine cylinder jacket. Tempered water for the latter is far better while the compressor cylinder will stand colder water.

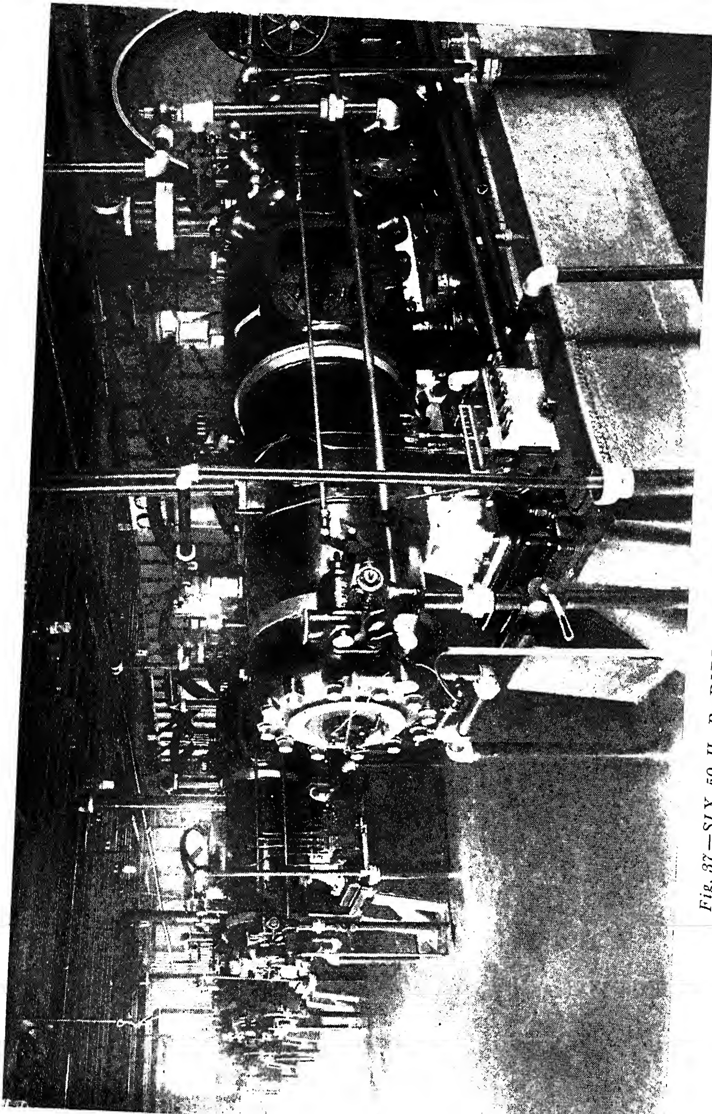


Fig. 37—*SIX 50 H. P. DIRECT DRIVEN TWO STAGE COMPRESSORS*

Blending—The gravity of gasoline may be reduced by mixing with it a quantity of lower gravity gasoline or naphtha. For instance, 50 lb. of 86 deg. gravity gasoline mixed with 50 lb. of 56 deg. gravity gasoline will give 100 lb. of 71 deg. gravity gasoline. This does not, however, result in a stable mixture if left unconfined, as the lighter gravity gasoline will gradually evaporate from the mixture.

Evaporation Losses in Blending—(George A. Burrell)—"The following table shows the results of some blending tests made by the author. The condensate, as it was drawn from the storage tank, was allowed to stand in graduated vessels, and the loss sustained by evaporation over different periods of time was noted. The containers were graduated glass cylinders having a capacity of 1,000 c. c. Their inside diameter was 2⅜ inches and they were 13 inches high. Some of the same condensate, as it was drawn from the storage tanks, was also mixed with naphtha and allowed to stand and the loss noted."

EVAPORATION LOSSES OF DIFFERENT MIXTURES OF CASINGHEAD GAS CONDENSATES AND REFINERY NAPHTHAS

Test No.	Proportions in mixture		Specific gravity of—		Specific gravity of mixture	End of 1 hour		End of 2 hours	
	Condensate	Naphtha	Condensate	Naphtha		Specific gravity	Loss	Specific gravity	Loss
	per cent	per cent	deg. Baume	deg. Baume	deg. Baume	deg. Baume	per cent	deg. Baume	per cent
1......	50	50	93	60	76.5	76	4	75	10
2......	70	30	93	44	76	75.5	6	74.5	14
3*a*.....	70	30	95	44	74.5	74	13	72.5	20
4*a*.....	50	50	95	44	67	65.5	8	65	16

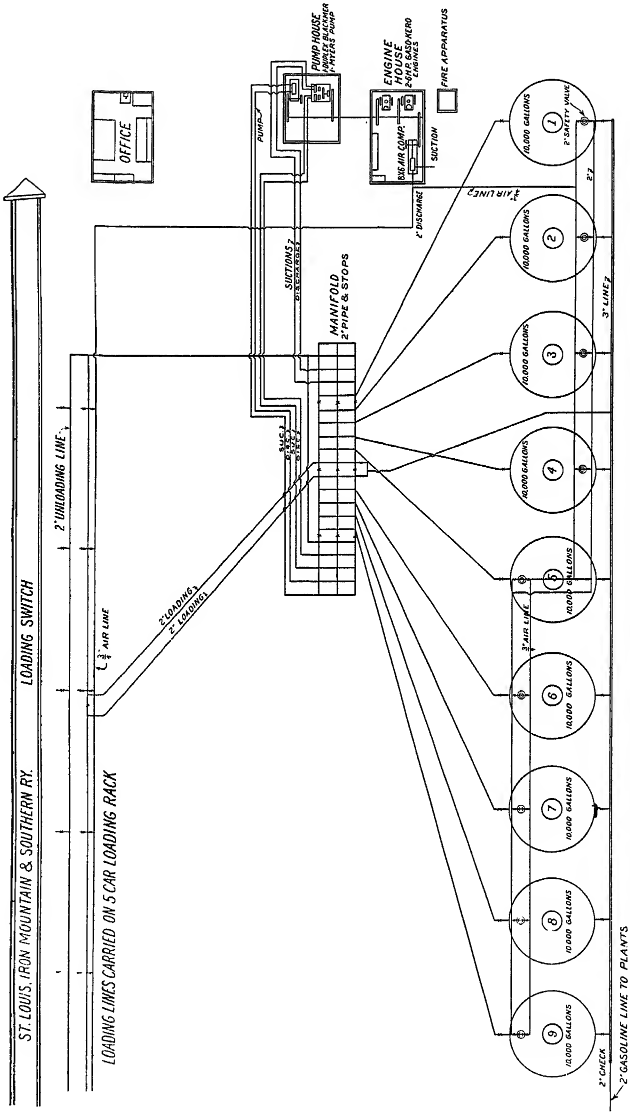


Fig. 38—PLAN OF BLENDING STATION, MANIFOLD, AND LOADING RACK

Test No.	End of 3 hours		End of 4 hours		Proportions in mixture		Specific gravity of—		Specific gravity of mixture
	Specific gravity	Loss	Specific gravity	Loss	Condensate	Naphtha	Condensate	Naphtha	
	deg. Baume	per cent	deg. Baume	per cent	per cent	per cent	deg. Baume	deg. Baume	deg. Baume
1......	75	12	74	16	50	50	93	60	76.5
2......	73.5	20	72.5	24	70	30	93	44	76
3*a*.....	72	26	71.5	29	70	30	95	44	74.5
4*a*.....	64	20	64	22	50	50	95	44	67

Test No.	End of 5 hours		End of 6 hours		End of 7 hours		End of 24 hours		Temperature of atmosphere	
	Specific gravity	Loss	Specific gravity	Loss	Specific gravity	Loss	Specific gravity	Loss		
	deg. Baume	per cent	deg. Baume	per cent	deg. Baume	per cent	deg. Baume	per cent	deg. fahr.	deg. cent.
1....	74	18	73	22	70.5	31	67	43	65 to 70	18 to 21
2....	71.5	29	71	30	.....	.....	.....	.....	....	....
3*a*...	71	30	69	34	68.5	37	65	50	60 to 70	16 to 21
4*a*...	63	25	62	30	61	36	56	54	60 to 70	16 to 21

a In conducting this test the mixture was exposed to the atmosphere to a greater extent than in tests 1 and 2. It was poured from one vessel to another eight times, thus exposing more liquid surface to the atmosphere and causing more rapid evaporation than would have occurred if it had been allowed to remain in the same vessel all the time without disturbance.

Boiling Point—From the time gasoline is released from the accumulator tanks, it boils until it reaches the temperature of the surrounding tank. As it boils, the boiling point rises steadily. If the boiling stops at any time due to any drop in temperature in the surrounding tank, it always begins

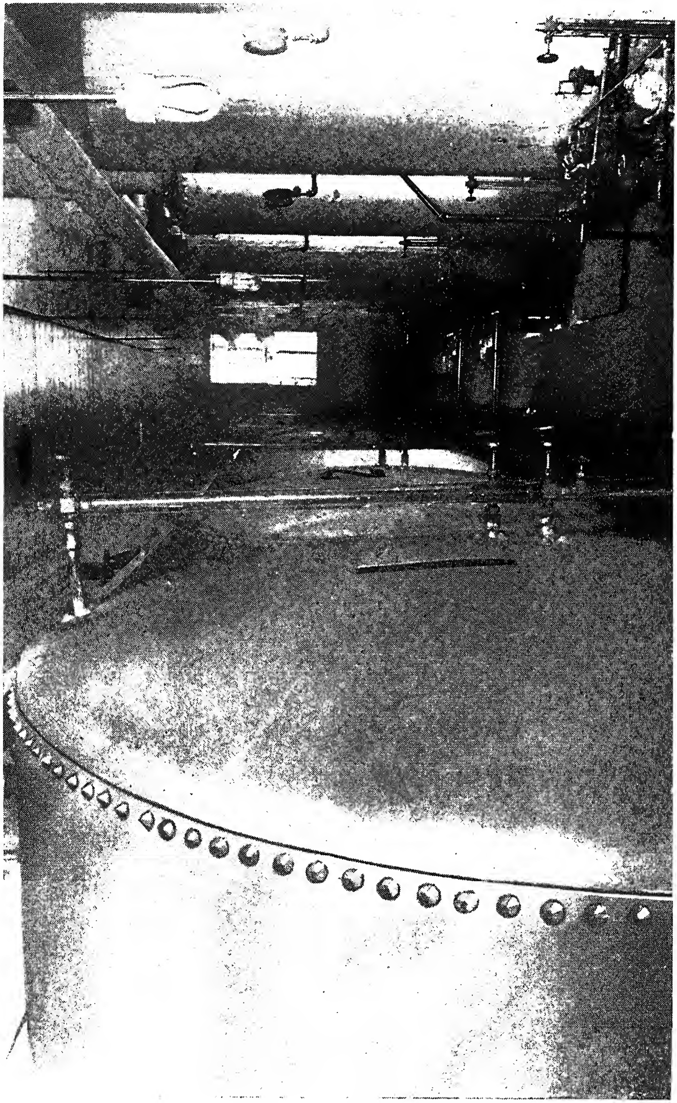


Fig. 39—ACCUMULATING AND BLENDING TANKS

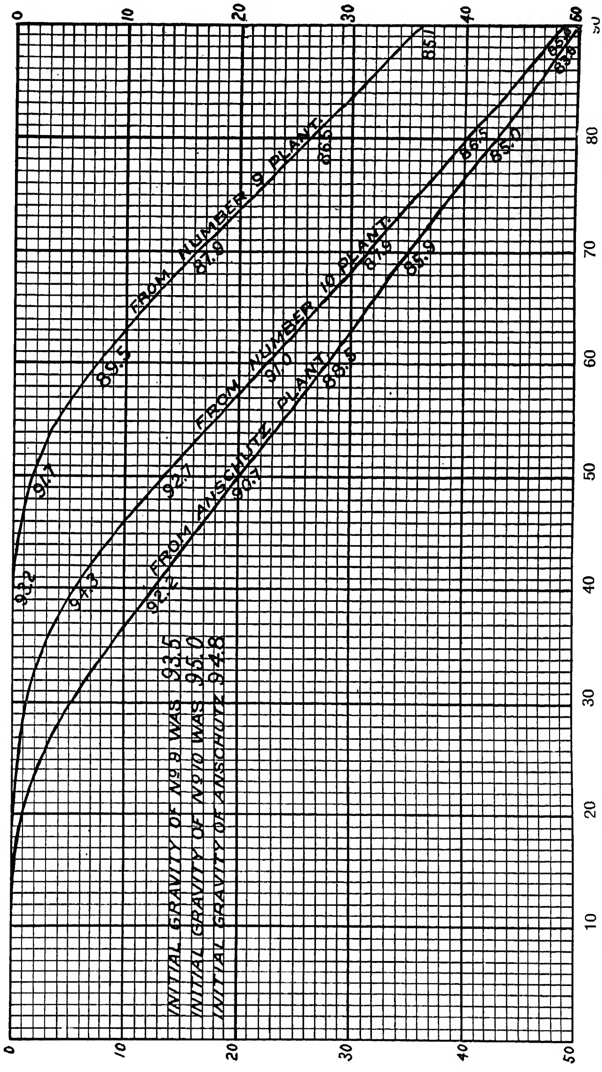


Fig. 40—Boiling points in degrees Fahrenheit. Gravities of casinghead gasoline at different boiling points showing percentage of loss

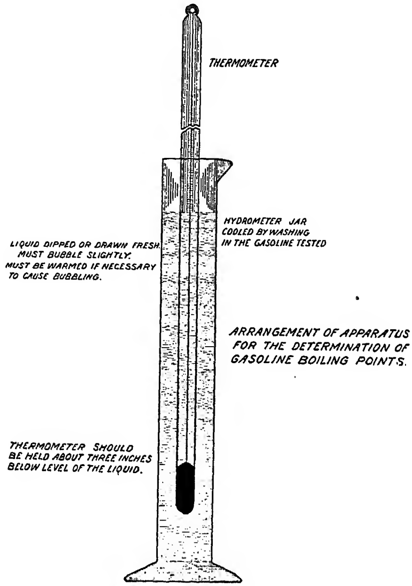


Fig. 41—METHOD OF TAKING THE BOILING POINT OF GASOLINE

to boil just where it left off when there is a rise in temperature. Boiling is usually most pronounced from 10 a. m. to 4 p. m., i. e., during the hot period of the day.

The air first starts to come out of the gasoline when it is heated and care must be taken not to mistake the small air bubbles for gas forming. As soon as the bubbles begin to come up repeatedly and grow larger as they come near the top the boiling point should be taken. Sometimes when the boiling point is taken the liquid will not begin to bubble until it has reached five or ten degrees higher than the true boiling point. This seems to be the case when the liquid is exceedingly pure and clean.

Boiling is best started from a point or particle. If no rough surface or point is present, the boiling often fails to

start at the proper time. To insure getting the right boiling point, a little pebble or a little fresh earth should be put into the sample before the test is taken.

Transporting Gasoline from Plant to Loading Rack—After the gasoline is blended it is stored in tanks built at a reasonable distance from the plant as a matter of safety. A pipe line is used to transport the gasoline from the storage tanks to the tank car at the loading rack. A specially designed pump is used to force the gasoline through the pipe line. Residue gas under high pressure is quite commonly used to run the pump. As these lines need not be large in size, galvanized pipe is most commonly used. The line should be buried to protect it from the heat of the sun.

It is a very interesting fact to note the large number of loading racks formerly used for loading oil at the nearby shipping points to some of the large oil pools, that recently have been changed and are now used for loading gasoline.

Residue Gas—Residue gas is the gas coming from a gasoline plant after the gasoline has been extracted. On account of this gas being higher in B. t. u. than natural gas the latter is hardly the correct name to apply to it.

The volume ratio of dry residue gas to the wet gas before the gasoline is extracted varies, depending upon the the quantity and quality of gasoline extracted. Five hundred or more cubic feet of dry gas will remain after extracting the gasoline from 1,000 cubic feet of wet gas.

Some casinghead gas will run greater than 2,500 B. t. u. to the cubic foot, while the average natural gas will run approximately 1,000 B. t. u. The extraction of gasoline by the compression method from one cubic foot of casinghead gas lowers the B. t. u., but on account of the impossibility of condensing and holding all the gasoline in the gas the residue gas may carry as high as 1,500 B. t. u., making it an exceptional gas for all purposes that natural gas is used.

Fig. 42—ABSORPTION PROCESS PLANT USED ON RESIDUE GAS

As the absorption process is generally applied to "lean" natural gas under high pressure which may test as low as .64 or lower in gravity and may only produce as low as one tenth or less of a gallon of gasoline to the 1,000 cubic feet of gas there is very little change in the gravity or in the B. t. u. in the gas. In extracting gasoline from "lean" natural gas by the absorption process the term residue is not applied to the gas after the gasoline has been extracted but it is properly termed natural gas.

Residue Gas and Absorption Method—Some companies state that it is profitable to apply the absorption process to the residue gas before distributing the gas for power. This is done by installing a system of large pipe coils as shown in Fig. 42 page 151.

The number of coils is dependent upon the quality of the gas and the amount to be treated. The gas must pass slowly through the oil to allow all of the gas to come in contact with all of the oil.

The oil is pumped into coils and the gas pressure in the coils gives the oil a flowing pressure to the steam still. The inlet and outlet of oil lines should be so regulated as to keep a constant level in the coils.

Torch oil or mineral seal oil can be used successfully.

A glass gauge can be installed on each joint of 12-in. pipe to assist in maintaining a constant oil level in the coil.

While the results may be judged by the gasoline recovered in the still, an analysis of the gas before and after entering the coils will more accurately determine whether the coils are operated successfully or not.

Carbon Black—It is a well known fact that the residue gas coming from a gasoline plant is very high in hydrocarbons. The opportunity of making carbon black from this gas should prove to be a profitable proposition.

There are many plants from which the residue gas is allowed to go to waste into the atmosphere due to the fact

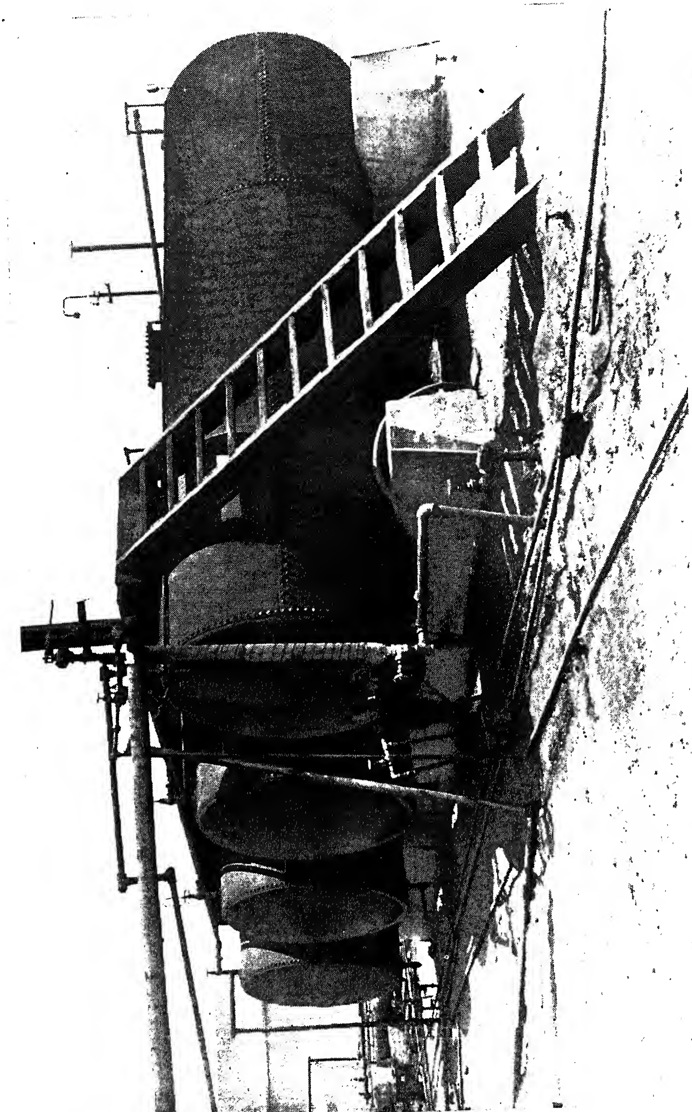


Fig. 43—STEAM STILL FOR REFINING OIL FROM ABSORPTION PLANT AS IS SHOWN IN FIG. 42

that there is no market nearby. In cases of this kind the installation of a carbon black plant in conjunction with the gasoline plant ought to be a profitable proposition. On account of the residue gas or any gasoline gas being so extremely heavy it would be advisable to place the carbon making plant at a safe distance.

It requires about 1,000 cubic feet of natural gas to make one pound of carbon black. This gas referred to is a gas of about .68 gravity. No doubt it would require less than 1,000 cubic feet of the average residue gas to make one pound of carbon black.

The operation of making carbon black is very simple. It consists of burning the gas without mixture with air—i. e., no air mixers—under a series of sheet iron shields which collect the carbon from the yellow flame.

The type of burner used is the old style lava tip originally used for lighting purposes with artificial gas. Many thousand tips are used at one plant.

The carbon is scraped off the shields and packed for shipment in 12½ lb. sacks.

Plants of this character require very little labor and can be run under the supervision of the regular plant foreman thus carrying little or no overhead expense.

Carbon black is mainly used in printers' ink, and is therefore a very necessary article. Every book or newspaper we read carries evidence of its usefulness.

Since the European war started a new use has been found for carbon black. Before the war tire makers imported from Germany oxide of zinc which was used in the outer rubber covering of the tire to protect the rubber. It gave the tire a white color. Since the importation of oxide of zinc has been cut off the tire makers on experiment, found that carbon black was far superior for tires hence the black faced tire now so commonly used.

This new market greatly stimulated the carbon black industry and caused a raise in the price.

The market price of carbon black at this writing, 1916, is from 10 to 15 cents per pound.

HAZARDS OF HANDLING GASOLINE

(*From Technical Paper No. 127, Petroleum Technology No. 28, Bureau of Mines.*)

Detailed Precautions Concerning the Handling of Gasoline—(By George A. Burrell)—"No open light or flame of any kind, nor any machine or belt capable of producing a spark should be allowed in the room where the gasoline is being used. All shafting and machines with belts that are liable to cause a static electric spark should be well grounded.

Only incandescent electric lights should be used, and these should be provided with guards to prevent their being smashed.

All electric switches, fuses, etc., should be outside the room.

Danger signs should be posted on all doors opening into the room, warning against the carrying of open lights of any kind inside.

Oily waste should at all times be placed in a safe receptacle to avoid the danger of spontaneous combustion. Oily waste will decay, smolder, and in time burst into flame. Sawdust when soaked with oil drippings will do the same thing, and its use should be forbidden. Sand is a safe material to use as an absorbent of oil.

A dangerous practice, common in many garages, is the cleaning of automobile parts with gasoline from an open can. Employees find it easy to clean grease and oil from the motor and other parts with a brush saturated with gasoline, and the gasoline is readily ignited by a spark. Such a spark may be caused by striking two pieces of metal to-

gether, by the ignition system on the automobile when the starting crank is turned, and in other ways. In one instance a nut that stuck was struck with a wrench, causing a spark. The car was instantly enveloped in flame.

When the use of an open pan is necessary the opening should be as small as possible and a cover should be provided. The cover should be put on whenever the pan is not in use.

Signs should be posted prohibiting an open flame near the place of storage or near a pump or other handling apparatus. The signs should explain the danger involved and give instructions for safe methods of operation.

Empty gasoline barrels should be stored with bungholes down, in safe places in the open air.

Rooms in which explosive or dangerous gases or vapors are used or generated should be safely inclosed, and should be provided with an improved system of ventilation.

Gasoline vapor is heavier than air, and a suction fan should be used to insure proper ventilation.

Joints in tanks, pipes, conveyors, etc., used for storage of explosive liquids, gases, or vapors should be kept tight.

Before work is done on vessels, pipes, etc., sufficient time should be given to allow gas to escape.

Special care should be exercised before work requiring the use of heat or flame is done. Apparatus that has contained explosive gas should be filled with water or steam to force out the gas.

Extinguishing Burning Liquids—There are two principal methods of extinguishing burning liquids, as follows:

1. To form a blanket of gas or solid material over the burning liquid and cut off the air (oxygen) supply.

2. To dilute the burning liquid with a non-inflammable extinguishing agent that will mix with it.

Water may be used for extinguishing burning liquids, such as denatured alcohol, wood alcohol and acetone, that are miscible with it. If such a liquid as gasoline, which is not miscible with water, catches fire, the application of water produces little or no effect except to spread the burning liquid, and thus scatter the fire over a larger area. However, the application of a large quantity of water to a small quantity of burning oil, by its cooling effect, may aid in extinguishing the fire.

Of materials used to form a blanket of gas or solid material over burning liquid, thus cutting off the oxygen supply, several are in common use. These include sawdust, sand, carbon, tetrachloride, and the so-called foam or frothy mixtures.

The efficiency of sawdust is due to its floating for a time on the liquid and excluding the oxygen of the air. Sawdust itself is not easily ignitible, and when it does ignite burns without flame. The character of the sawdust and its moisture content is of little or no importance. It may be well handled for extinguishing small fires, when just started, by means of long handled wooden shovels.

Sand probably serves about as well as sawdust for extinguishing fires on the ground, but is heavier and more awkward to handle. When thrown on a burning tank it sinks, whereas sawdust floats.

Carbon tetrachloride, the basis of various chemical fire extinguishers, if thrown on a fire forms a heavy non-inflammable vapor over the liquid, and mixes readily with oils, waxes, japan, etc. The vapor is about five times as heavy as air. Much of the carbon tetrachloride contains impurities that give it a bad odor, but when pure its specific

gravity is 1.632 at 32 deg. fahr. When thrown on a fire, it produces black smoke, the hue of which is caused by unconsumed particles of carbon. Pungent gases are also produced probably hydrochloric acid gas and small volumes of chlorine gas. Although the fumes are pungent, brief exposure to them does not cause permanent injury.

The efficacy of carbon tetrachloride depends largely on the skill of the user. If liquid in a tank is on fire, the height of the liquid is important. When the liquid is low, the sides of the tank form a wall which retains the vapor, but when a tank is nearly full of a highly volatile liquid like gasoline, only the most skilled operator can extinguish the fire.

For smothering some small fires of burning gasoline an ordinary blanket may be used.

Use of Foam or a Frothy Liquid Mixture as an Extinguisher Installations embracing the use of foam or frothy liquid mixtures to extinguish fires in large gasoline storage tanks originated in Germany. For such an extinguisher two liquids are caused to mix in a tank, whereupon foam is produced. The tank is made air tight and sufficiently strong to permit the foam to be forced out under pressure of a gas (carbon dioxide) simultaneously generated. The frothy mixture owes its efficacy to its blanketing action in excluding air (oxygen) from the fire. It is stiff and shrinks only slightly in volume even after half an hour. In one installation water, bicarbonate of soda, and soap bark are used in one tank, and acid in another tank. A fusible link, which will melt at 212 deg. fahr. releases a hammer, which breaks the glass tank containing the acid. The released acid is led through two perforated pipes into the solution, producing a violent ebullition of foam, which finds its way into the tank of burning oil.

In some large plants gasoline is continually stored under the pressure of noninflammable gas, as nitrogen or carbon

dioxide. In other plants it is stored in a tank, which is always kept filled, no air being admitted at any time. The tank may be filled with all gasoline or part gasoline and part water, water being pumped into the tank to force out the gasoline, when desired. The water may be drained off when more gasoline is to be added to the tank.

Relation of Properties of Gasoline and Gasoline Vapor to Inflammability—Some grades of gasoline, particularly the better grades used to drive automobiles, are much more hazardous to handle than are others. They mix with air in larger proportions and pass into the vapor form (evaporate) more rapidly, and hence more quickly render a given volume of air explosive than do the heavier grades, such as are used for cleaning purposes and for fuel in the engines of some motor trucks and other large internal-combustion engines.

Action of Gasoline Vapor in Air—Gasoline vapor mingles with air in the same manner that water vapor does. At any particular temperature a definite proportion of water vapor will be found in the atmosphere if it has become completely saturated, a condition that seldom exists. Usually a limited supply of water has been given off into the air, and the atmosphere is spoken of as having a certain relative humidity, meaning that the saturation is incomplete or that more water vapor could exist in the air were a source of moisture available. In a similar manner gasoline vapor mixes with air. The amount of vapor carried will depend on the temperature of the air and the readiness with which the vapor can be obtained.

If gasoline is exposed to the air of a room and for a long enough time, the air will contain at a certain temperature a fixed proportion of gasoline vapor, differing for different grades of gasoline, that can not be exceeded. The author has worked out the values for four different grades. The results for a temperature of 17.5 deg. cent. (63.5 deg. fahr.) are shown in the following table:

Proportions of Different Grades of Gasoline Vapor that Air will Carry at a Temperature of 17.5 deg. cent. (63.5 deg. fahr.)

Grade of Gasoline	Proportion of Gasoline vapor (per cent.)
Cleaner's naphtha	5.0
64 deg. Baume gasoline	11.0
69 deg. Baume gasoline	15.0
73 deg. Baume gasoline	28.0

It will be noticed that air will hold almost six times as much vapor from the lighter gasoline as from the heavier cleaner's naphtha. If the lighter and better grades of gasoline are heated, their vapors, when a light is applied, also flash and burn at lower temperatures than do the heavier grades. This difference does not mean that some gasoline is a dangerous inflammable liquid and some is not. All grades are classed as highly inflammable and dangerous liquids.

Comparison of Inflammability of Gasoline and of Gasoline Vapor—If one takes the cover off a full pail of tightly inclosed gasoline and applies a match to the surface, the gasoline will flare up and burn as long as the gasoline lasts. On the other hand, if one puts a few drops of gasoline in a small tightly inclosed pail, waits a few minutes, and then introduces a flame or an electrical spark a violent explosion will most likely result. In the first case the vapor burns as fast as it comes from the gasoline, and mixes with the oxygen of the air. In the second case the oil vaporizes in the pail and mixes uniformly with the air therein to form an explosive mixture and upon ignition explodes. Consequently, when one hears of a disastrous gasoline explosion one may be sure that the explosion resulted from the mixing of the vapor from the gasoline with air in the proportions necessary to form an explosive mixture.

One gallon of gasoline when entirely vaporized produces about 32 cubic feet of vapor. If a lighted match could be applied to pure gasoline vapor in the absence of air no fire

or explosion would result. Gasoline liquid or vapor, like any other combustible material, needs the oxygen of the air in order to burn.

Explosive Range of Mixtures of Gasoline Vapor and Air—It is fortunate that gasoline vapor, like other gases and vapors, needs a certain proportion of air before an explosion can take place. The author found that in 100 parts by volume of air and gasoline, an explosion will not take place if there is less than 1.4 parts of gasoline vapor or more than 6 parts.[a] In other words, the explosive range is between 1.4 and about 6 per cent of vapor. Flashes of flame will appear in mixtures containing considerably smaller and larger proportions of vapor, and considerable pressure will be developed, but propagation through the mixture will not take place.

Although the range of explosibility mentioned is narrow as compared to that of many other mixtures of combustible gases and air, yet the proportion of gasoline vapor representing the lower limit is small, and indicates the great importance of not allowing even a little gasoline to be exposed in a room, because of the small quantity of vapor needed to make an explosive mixture with all the air in the room. If 1 gallon of gasoline is allowed to change completely into vapor simply by exposing it to the room air, and if the room is gas-tight, the 1 gallon can render explosive 2,100 cubic feet of air, the amount contained in a room measuring 21 by 10 by 10 feet.

In the actual use of gasoline such conditions seldom exist. However, an assumed case may be that of a person filling an open pail from a larger tank or using gasoline for cleaning. When the pail is first filled with the gasoline, a small volume of pure gasoline vapor forms over the surface of the gasoline. Just above this layer of pure gasoline

[a] Burrell, G. A., and Boyd, H. T., Inflamability of mixtures of gasoline vapor and air; Technical Paper 115, Bureau of Mines 1915, p 10.

vapor is a mixture of vapor and air; at some point there will be an explosive proportion, and farther away from the pail there will be a small proportion of vapor, and finally still farther away no vapor at all, but pure air. However, all the time the user of the gasoline is at work, the vapor keeps forming, from both the gasoline in the pail and that applied to the object being cleaned, rendering more and more air inflammable or explosive, until finally there will exist a dangerous atmosphere that may completely sorround him, so that a chance ignition will envelope him in flames and perhaps cause great damage to property. Ignition of the gasoline vapor may take place even some distance from the gasoline in a room adjoining the room in which the person works. As the gasoline evaporates, and more and more vapor is given off, it mixes with air farther and farther from the gasoline, and, if the evaporation lasts long enough, may travel to an adjoining room, where it may be ignited. On ignition a sharp flash will travel back through the adjoining room to the room where the gasoline is.

Resume—At ordinary temperatures air will hold about 5 to 28 per cent of gasoline vapor. As gasoline vapor is about three times as heavy as air, in a room containing a mixture of the vapor with air the vapor is found in largest proportion near the floor.

The limits of explosibility of mixtures of gasoline vapor and air are between 1.4 and 6 per cent of gasoline vapor, although dangerous flashes may be produced with mixtures, containing less and more than these proportions. In other words, there is needed only a small proportion of gasoline vapor to render air explosive—1.4 cubic feet of the vapor to 97.5 cubic feet of air. One gallon of gasoline can under ideal conditions render 2,100 cubic feet of air explosive.

A dangerous feature of gasoline vapor is that it may travel a considerable distance from the gasoline and there

be ignited, the flash traveling back to the container of the liquid and causing a roaring fire in a few seconds."

Dangers of the Electric Flash Light—The pocket electric flash light while generally considered perfectly safe in gas is dangerous when the light is first equipped with a new battery, unless the light is turned on away from the gas zone and kept turned on while in the gas and till it is carried away from the gas.

The danger lies in releasing the button on the light when equipped with a new strong battery at which time the act of releasing the button is liable to cause a make-and-break spark strong enough to cause an explosion.

To Extinguish Fires—The fire extinguisher is very effective in extinguishing small fires. It is good policy to have in an accessible location, a hand chemical cart holding at least twenty-five gallons. This size cart will extinguish a fire or blaze several feet in height.

Other methods employed are to have at various points around a plant, quantities of sand or salt. The sand and salt have a tendency to smother gasoline fires.

PART SEVEN

Gasoline Plant—Absorption Method

"Lean" Natural Gas—"Lean" natural gas is the name applied to natural gas that carries a small percentage or trace of gasoline often amounting to only one tenth of a gallon per thousand cubic feet.

Nearly all high pressure pipe lines show some condensation of gasoline from the gas. The presence of free gasoline in a plain end pipe line invariably causes an extra heavy expense to the pipe line company on account of the constant repairs necessary. The gasoline softens and decomposes the rubber rings at the joints, causing leaks and blowouts. There are some rings made from a composition that withstands the action of gasoline better than rubber.

While the extraction of gasoline from "lean" natural gas is a profitable proposition in itself, you will also find that the life of the rubber or composition rings is prolonged and with a corresponding decrease in line loss from leakage, the overhead expense is greatly reduced.

On many high pressure gas lines the drips will show quantities of gasoline. This should not be taken as conclusive that the gas carries a sufficient amount of gasoline per thousand cubic feet, to warrant the installation of an absorption plant. Though the amount of gasoline taken out of the drips may be large in quantity, it is impossible to determine from this condition just how much gasoline a thousand cubic feet of gas will carry.

The only true method to accurately determine the quantity of gasoline in a thousand cubic feet of gas is by actual test as described below.

Extraction of Gasoline from Natural Gas by Absorption Methods—(By George A. Burrell, P. M. Biddison, and S. S. Oberfell. Proceedings of Natural Gas Association, 1916)—

The Development of the General Process of Passing Natural Gases Through Oils or Naphtha for the Extraction of Gasoline—"The idea follows closely the process of extracting benzole, toluol, and other vapors (light oil) from gases made by destructively distilling coal. In this process the gases are caused to flow at about atmospheric pressure counter current to a stream of wash oil, a petroleum distillate as so called "straw" oil or "mineral seal" oil or a coal tar distillate such as creosote oil. Absorbing towers in which this is accomplished are 50 to 75 feet high and about 10 to 15 feet in diameter. After the benzole and toluol have been scrubbed from the gas, the charged oil is sent to steam stills where the benzole and toluol are extracted. The process is continuous in that the absorbent oil is used over and over again. The process has been used for many years in Germany and to a very large extent during 1915 and 1916 in the United States. Many types of absorbers and steam stills and different conditions of temperature and pressure were employed before a standard procedure was evolved. The difference between the process of extracting gasoline from natural gas and extracting benzole and toluol from coke oven gases is that with the natural gas, the absorption is conducted at high pressure. This is an economic necessity because the natural gas at present being treated by the absorption process exists at this high pressure, and cannot be profitably treated any other way. The transportation system must not be disturbed.

There might also be mentioned a process in vogue for a number of years past, and practiced at some refineries, of subjecting uncondensed gas and petroleum vapors from stills to absorption in naphtha, thereby increasing the gasoline yield considerably. Also a scheme sometimes practiced of passing natural gas through crude oil in tanks, and later compressing and cooling the natural gas to obtain the gasoline extracted from the oil.

The first large scale installation for extracting gasoline from natural gas was placed at Hastings, W. Va., by the Hope Natural Gas Company of Pittsburgh, Pa. The plant was put in operation in 1913 as a result of the Saybolt experiments. The process consists in causing the natural gas to bubble up through mineral seal oil, the latter being then sent to steam still for the separation of the gasoline and the absorbent oil being used over and over again. The gas is passed through the absorbing oil at the high pressure of the line. The hot oil from the stills is cooled in a double pipe cooler or exchanger by the cold oil enroute to still and further cooled by passing through pipes upon which running water falls.

The general process, except for the utilization of the gas under high pressure, is identical with the process of absorbing benzol and toluol vapors from coke-oven gases.

The process of extracting gasoline from natural gas by passing the latter through oil, simply consists in the solution of the gasoline in the absorbent. In passing natural gas with its gasoline vapor through an absorbent, there will occur a point in the solution process when a particular oil will not take up any more gasoline. The authors determined that in the case of mineral seal oil this saturation was 28 per cent, as regards tests they conducted. In conducting the test natural gas was passed through mineral seal oil, using the small absorber shown in figure 46. By a percentage saturation of 28 is meant that the amount of gasoline absorbed was 28 per cent of the final total volume of gasoline and oil.

But in the practical work of absorbing gasoline from natural gas, the saturation percentage of the gasoline in the oil cannot be carried that far. It was found from actual tests that when the saturation of the gasoline exceeded 4 per cent, some of the gasoline in the natural gas was passing through the oil unabsorbed, i. e., the extraction was not

complete. As a saturation percentage of 4 per cent was exceeded more and more gasoline was absorbed, of course, from the natural gas* but at the same time an increasingly small amount of gasoline appeared in the exit gases. This small amount was always less than the amount absorbed until a saturation of 28 per cent was reached, when the amount absorbed was equal to the amount given off, i. e., a condition of equilibrium was reached.

Two different oils were used as the absorbing medium in extracting gasoline from the natural gas in conjunction with those tests in which steam distillation was used to finally separate the gasoline from the absorbent. These oils were petroleum distillates. Their characteristics as determined by E. W. Dean, petroleum chemist of the Bureau of Mines, follow:

Mineral Seal.

Flash Point (Pensky-Martin closed apparatus)	135 deg. cent., 275 deg. fahr.
Burning Point (Pensky-Martin open apparatus)	160 deg. cent., 311 deg. fahr.
Specific Gravity (Water=1)	.850

Upon distillation the first drop appeared at 225 deg. cent. (405 deg. fahr.) and 6.2 per cent distilled up to 275 deg. cent. (527 deg. fahr.)

Straw Oil.

Flash Point	180 deg. cent., 361 deg. fahr.
Burning Point	208 deg. cent., 416 deg. fahr.
Specific Gravity (Water=1)	.851

First drop distilled at 250 deg. cent. (482 deg. fahr.) and began to distill in quantity at 275 deg. cent. (527 deg. fahr.)

The main requirement of an absorbent oil is that its boiling points vary sufficiently from the boiling points of the gasoline so a separation of the two can be made by distillation.

Description of Experimental Plants Using Mineral Seal Oil and Steam Distillation—While the tests were under

*This would occur up to 28 per cent saturation.

way, using the small scale experimental plant shown in figure 46, tests on a much larger scale were made with the plant shown in figure 44. This plant was capable of continuous operation in that natural gas was continuously passed through the absorbing oil and the latter after leaving the absorbers, charged with gasoline, were pumped to the steam stills where the gasoline was removed and the oil pumped back to the absorbers to receive another charge of gasoline. This plant has a capacity of from 15,000 to 30,000 cubic feet per hour.

A diagrammatic view of the plant is shown in figure 44.

The gas enters the absorbing tank at C and the oil enters at B. Together they pass into the T pipe D and pass from there through many small holes into the oil contained in the absorber A. The gas bubbling up through A is stripped of its gasoline by absorption in the oil and passes out of the absorber as shown and goes on its way to the cities and other places for consumption.

The oil charged with gasoline passes first to the weathering tank E, where the lighter portions of the gasoline are released through the safety valve. (Set at about 3 lb. per square inch.)

Next the oil enters the pump F and is pumped through the heat exchanger G and from there into the rock tower H of the steam still K. Live steam enters this still and distills the gasoline from the oil. The cooler M is provided to separate the water (condensed steam) from the gasoline. The gasoline is condensed in the condenser N and flows out of the system at the gasoline drip.

The hot oil after having been freed of its gasoline is passed through the heat exchanger G (thereby heating the oil passing to the still) and from No. 1 pump is forced through the water coils O, upon which running water drops. The cooled oil then passes into the absorber A to receive

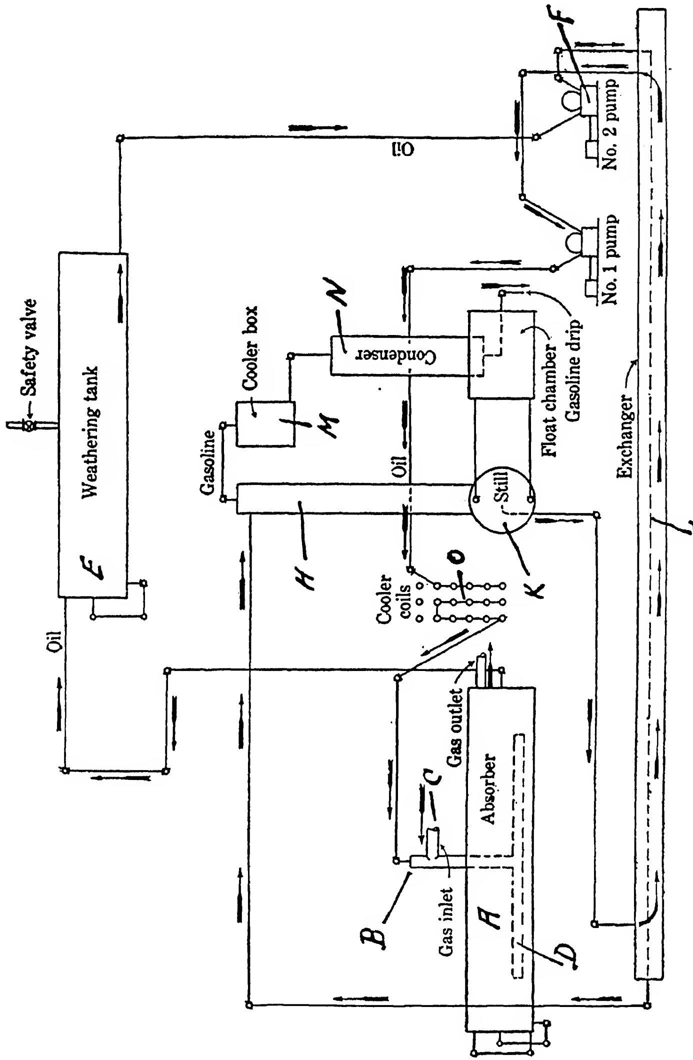


Fig. 44—EXPERIMENTAL PLANT FOR ABSORBING GASOLINE FROM NATURAL GAS

another charge of gasoline. The operation is continuous, the oil being used over and over again.

In addition to the type of absorber shown at A in figure 44, several other types of absorbers were used. The most efficient was a vertical or tower absorber shown in figure 45. Oil enters as shown at A and drops onto and through a column of stones of about the size of a fist. Gas enters near the base of the tower and flows counter current to the oil and out of the gas pipe at the top of the column.

Yield of Gasoline Using the Small Absorber Shown in Figure 46 and the Plant Shown in Figure 44—In Table 1 are shown data of tests using the "plant" shown in figure 44. In Test No. 1 the tower absorber was used. In Test No. 2 the absorber used was connected with the plant. The tower absorber gives the best results.

In Table 2 are shown some results using the small absorber. The yield obtained with the small absorber exceeded that obtained with the larger absorber by about 0.3 of a pint.

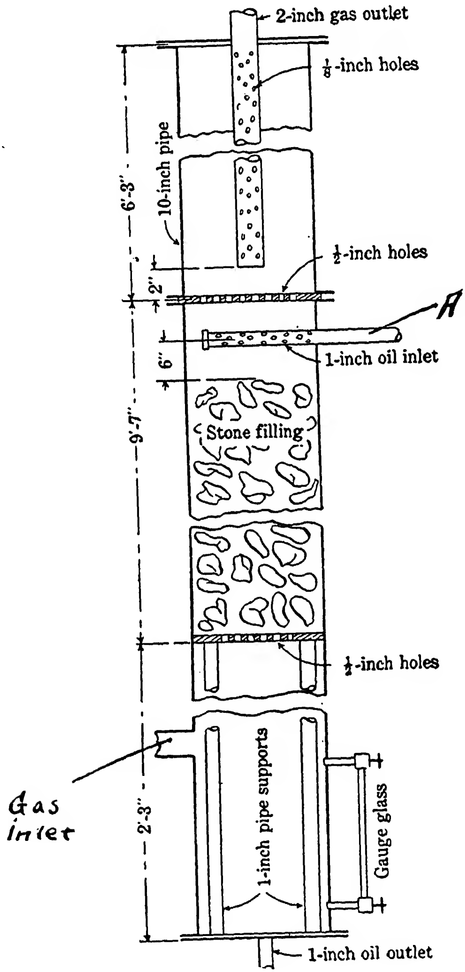


Fig. 45—VERTICAL ABSORBER WITH STONES

TABLE 1

Test of Natural Gas Using Different Absorbers

Kind of Absorber	Tower Absorber				Bubbling Absorber			
Test No	1				2			
Time	8	9	10	11	8	9	10	11
Pressure at inlet to absorber, lb. per sq. in.	222	215	211	211	225	220	216	215
Pressure on still, lb. per sq. in.	3	3	2.75	2.75	3	3	2.75	2.75
Temperature of oil, deg. fahr.	58	64	66	68	66	66	66	68
Temperature of oil outlet still, deg. fahr.	207	210	208	209	212	212	212	210
Temperature of vapor outlet cooler, deg. fahr.	142	170	164	176	170	172	184	172
Temperature of cooling water, deg. fahr.	52	52	52	52	52	52	52	52
Temperature of still, deg. fahr.	218	216	216	216	216	216	216	215
Temperature of oil outlet absorber, deg. fahr.	54	58	60	62	60	58	60	68
Sp. gr. absorbing oil inlet to absorber, deg. B.	34.2	33.7	33.5	34.4	34.5	34.5	34.5	34.4
Sp. gr. absorbing oil outlet from absorber, deg. B.	36.4	36.2	36.0	35.8	35.0	35.2	35.0	34.4
Yield gasoline, c. c.	......	17000	16000	16310	......	9200	9600	11300
Gravity gasoline, deg. B.	......	85.2	85.5	85.8	......	80.3	80.3	82.3
Gravity of refrigerator gasoline, deg. B.	......	91.1	91.8	90.5	......	90.3	92.0	90.6
Volume of refrigerator gasoline, c. c.	......	1860	2200	2030	......	2335	2130	1810
Amount of gas passed, cu. ft.	73,800							
Yield of gasoline per 1000 cu. ft., total pints.	1.57				1.18			

Flow of gas.................24,600 cu. ft. per hr.
Gallons of oil circulated per 1000 cu. ft. of gas..7.9

Rate of flow of gas...........21,600 cu. ft. per hr.
Gallons of oil circulated per 1000 cubic feet of gas.8.7

Refrigerator gasoline means that obtained by condensing vapors escaping from the still and condensed by the water in the condenser.

TABLE 2

Tests with small absorber. Mineral seal oil used. Three absorbers in series for each test.

Test Number	No. 1 Test			No. 2 Test		
Number of absorber	1	2	3	1	2	3
Rate of flow of gas, cubic feet per hour	360	360	360	240	240	240
Cubic centimeters of oil used	1,750	1,500	1,500	1,750	1,500	1,500
Cubic feet of gas used	202	202	200	200	200	200
Temperature of oil, degrees fahr	58	60	62	60	60	64
Amount of oil and gasoline recovered	1,950	1,580	1,550	1,980	1,600	1,570
Saturation of oil with gasoline, per cent	7.9	2.3	0.4	7.0	2.1	0.2
Amount of sample taken for distillation test, cubic centimeters	650	527	517	660	533	523
Amount of gasoline obtained from sample by distillation, cubic centimeters	45	12	2	46	11	1
Calculated amount of gasoline, entire oil and gasoline recovered	135	36	6	138	33	1
Boiling point of gasoline, degrees fahrenheit	110–250	150–250	150–250	110–250	145–250	150–250
Cubic centimeters of oil used per 1,000 cubic feet of gas	8,750	7,500	7,500	8,750	7,500	7,500
Pints of gasoline recovered, obtained per 1,000 cubic feet of gas	1.42	0.36	0.06	1.46	0.35	0.03
Specific gravity of gasoline, degrees Baume	84	....	....	84	....	....
Total amount of gasoline from three absorbers, pints per 1,000 cu. ft. of gas	1.84			1.84		

Change in Composition and Quantity of the Natural Gas Before and After the Extraction of Gasoline—Tests which the authors made of the natural gas before and after treatment for the absorption of gasoline follow:

TESTS OF FRESH GAS

Combustion Analysis.

	Low Field Gas. Per Cent.	*Line L Gas. Per Cent.*
CO_2	trace	trace
CH_4	76.3	83.9
C_2H_6	18.4	11.7
N_2	5.3	4.4
Total	100.0	100.0

	Low Field Gas.	*Line L Gas.*
Specific gravity	0.68	0.63
Absorption in Russian white oil*	17.0	15.0
Gross heating value per cubic foot of 0 deg. cent. and 760 mm. pressure	1155.0 B. t. u.	1111.0 B.t.u.

The foregoing tests were made of gas that had not been treated by the absorption process. The following table shows tests of the same gas after it had been passed through absorbers containing mineral seal oil, and after gasoline had been extracted from it.

TESTS OF TREATED GAS

Combustion Analysis.

	Low Field Gas. Per Cent.	*Line L Gas. Per Cent.*
CO_2	trace	trace
CH_4	79.7	88.3
C_2H_6	14.1	7.9
N_2	6.2	3.8
Total	100.0	100.0

	Low Field Gas.	*Line L Gas.*
Specific gravity	0.65	0.61
Absorption in Russian white oil	16.7	14.0
Gross heating value per cubic foot at 0 deg. cent. and 760 mm. pressure	1111.0 B.t.u.	1087.0 B.t.u.

* The Russian white oil is used in the same way that Claroline is used, and described on page 32, Bull 88 Bureau of Mines.

Comments on Analyses — Differences between the natural gas before and after gasoline had been extracted are interesting. In the case of the low field gas, the heating value was lowered 44 B. t. u. or 3.8 per cent, due to the extraction of the gasoline. The specific gravity dropped from .68 to .65 and the proportions of paraffin hydrocarbons calculated as methane and ethane, were altered. In the case of Line L gas, the heating value was lowered 24 B. t. u. or 2.2 per cent and the specific gravity dropped from .63 to .61.

The amount of gas that disappeared by conversion into gasoline is very small. It can be calculated this way: one gallon of gasoline produces about 32 cubic feet of vapor, or one pint produces 4 cubic feet. In their experiments the authors extracted from one to two pints of gasoline per 1,000 cubic feet of natural gas or from 4 to 8 cubic feet of natural gas disappeared from each 1,000 cubic feet of natural gas treated.

Amount of Oil Used per Thousand Cubic Feet of Natural Gas to Obtain the Largest Yield of Gasoline—A large number of tests were made with different absorbers to determine the proper amount of oil to be used per 1,000 cubic feet of natural gas in order to obtain the highest yield of gasoline. It was found that using the absorber shown in figure 44 the best results were obtained when about 7 gallons of oil were circulated per 1,000 cubic feet of gas. Using the tower absorber shown in figure 45 the amount of oil circulated could be considerably decreased and just as good results obtained by circulating 4 gallons of oil per 1,000 cubic feet of gas. Instead of decreasing the amount of oil, the practice of the authors was to keep the oil rate at about 7 gallons and increase the gas rate. The best results were obtained with the tower absorber by passing about 28,000 cubic feet of gas per minute and circulating about 7 to 8 gallons of oil.

Distillation Test of Gasoline—The gasoline obtained by absorption in mineral seal oil and steam distillation rather consistently had a specific gravity on the Baume scale of about 80 deg. One of many distillation tests that the authors made of it are shown in Table 1. These tests were made on gasoline obtained from the large scale experimental plant shown in figure 44.

DISTILLATION TEST OF GASOLINE OBTAINED BY ABSORPTION METHOD

Experimental Plant. December 29, 1915.
Specific Gravity of Mixture=80 deg. Baume.

Distillation Temperature, Degrees Fahrenheit	*Amount of Distillate, by Volume, Per Cent*	*Specific Gravity of Distillate, Degrees Baume*
80–110	10	91.8
110–124	20	89.0
124–136	30	86.7
136–146	40	83.4
146–158	50	80.4
158–172	60	77.4
172–188	70	73.3
188–208	80	70.2
208–244	90	65.0
244–290	93	63.1
Loss	7	

This test shows the gasoline to be very high grade.

Evaporation Loss of Gasoline Obtained by Absorption Method from Natural Gas and a Comparison with Different Blends and with Refinery Gasoline. In Table 3 there is shown the loss by evaporation, using different grades of gasoline. The liquids were exposed in glass cylinders, 12 inches high, 4 inches in diameter, and of 1,000 cubic centimeters capacity. The first column shows the evaporation loss when the gasoline obtained from natural gas by the absorption process was exposed to the air. The second column shows the evaporation loss, using refinery gasoline obtained from the Standard Oil Company.

The absorption process gasoline lost 10.5 per cent at the end of the first hour. This is far better than casinghead gasoline, much of which will lose 25 to 30 per cent of its volume by "weathering" after standing one hour.

TABLE 3
EVAPORATION LOSS OF GASOLINE

Kind of Gasoline	*From Absorption Process*	*Refinery*
Specific gravity of gasoline at start, degrees Baume	81.1	60.4
Temperature of gasoline, degrees fahrenheit	56	62
Temperature of room, degrees fahrenheit	70	70
Volume of gasoline at start, cubic centimeters	1000	1000
Volume of gasoline after 24 hours, cubic centimeters	895	976
Volume of gasoline after 48 hours, cubic centimeters	840	955
Volume of gasoline after 72 hours, cubic centimeters	800	924
Specific gravity of gasoline after 24 hours, degrees Baume	79.6	.....
Specific gravity of gasoline after 48 hours, degrees Baume	76.5	.....
Specific gravity of gasoline after 72 hours, degrees Baume	76.0	58
Temperature of gasoline after 24 hours, degrees fahrenheit	56	.....
Temperature of gasoline after 48 hours, degrees fahrenheit	....	.....
Temperature of gasoline after 72 hours, degrees fahrenheit	61	60
Evaporation loss of gasoline after 24 hours, per cent	10.5	2.4
Evaporation loss of gasoline after 48 hours, per cent	16.0	4.5
Evaporation loss of gasoline after 72 hours, per cent	20.0	7.6

Vapor Tension Tests of Gasoline Obtained by Oil Absorption and Steam Distillation—Many vapor tension tests were made of the gasoline. Some of these tests are shown in the following table. It will be seen that the material does not develop excessive pressures with rise of temperature and that it comes well within the specification for gasoline that can be shipped in tank cars.

VAPOR PRESSURE TESTS OF GASOLINE PRODUCED BY OIL ABSORPTION AND STEAM DISTILLATION METHOD

Date	12/15/15	12/16/15	12/22/15	12/23/15
Specific gravity of gasoline, deg. Baume	79	78	77.5	81.5
Vapor pressure, at 70 deg. fahr., lb. per sq. inch	1.25	1.0	.5	1.25
Vapor pressure, at 90 deg. fahr., lb. per sq. inch	1.50	1.5	1.0	2.0
Vapor pressure, at 100 deg. fahr., lb. per sq. inch	2.75	2.5	2.5	4.75

Unconcensed Vapors from the Still—In the process of distillation of the gasoline from the mineral seal oil by means of steam, an appreciable quantity of uncondensed vapors escaped into the air, hence some of them were liquefied by passing the vapors through a 1 in. pipe about 8 feet long, inside another pipe 2 in. in diameter and 8 feet long. Compressed natural gas which had been used to run one of the oil pumps (in place of steam) was expanded through the larger pipe to cool and condense as much of the vapors as possible. A temperature of 0 deg. to 4 deg. fahr. was obtained in this manner. The following table shows the vapor pressure and other data regarding these condensed vapors.

DATA REGARDING UNCONDENSED VAPORS FROM STILL

Vapors from Condenser

130,000 cubic feet of natural gas used in the test and 450 cubic feet of vapor passed through refrigerator

Yield........................3.25 gallons per 130,000 cubic feet of natural gas used at plant.

Vapor tension test........................ 5 lb. at 70 deg. fahr.
8.25 lb. at 90 deg. fahr.
11 lb. at 100 deg. fahr.

Specific gravity of refrigerator gasoline............94.9 deg. Baume

Evaporation Test

Time, p. m.	1:15	1:20	1:35	2:00	2:15
Volume (cc.)	100	75	65	55	50
Temperature, deg. fahr.	....	60	70	84	90
Per cent loss	....	25	35	45	50

TABLE 4

Effect of pressure on yield of gasoline, using three apparatus in series like that shown at Fig. 46

Test No	1			2		
Date	January 26, 1916.			January 29, 1916.		
Time	2:48 to 3:58 P. M.			2:25 to 3:40 P. M.		
Kind of oil used	Mineral Seal.			Mineral Seal.		
Specific gravity of oil, degrees Baume	34.2			35.0		
Amount of oil used, cubic centimeters	1750	1500	1500	1750	1500	1500
Pressure on absorber, lb. per sq. in.	Atmospheric			20 lb. gauge		
Gas rate by meter, cu. ft. per hour	79					
Ratio, c. c. of oil to 1000 cu. ft. of gas	17500	15000	15000	17500	15000	15000
Cubic feet of gas consumed	100	100	100	100	100	100
Amount of liquid recovered, c. c	1770	1505	1510	1845	1515	1520
Sp. gr. of liquid recovered, degrees Baume	35.1	34.5	34.4	35	35.2	34.7
Temperature of liquid recovered, degrees fahr	68	67	66	66	68	69
Per cent saturation of liquid recovered	1.2	0.6	0.3	2.3	1.2	0.5
Increase in c. c. of liquid recovered	20	5	10	95	15	20
Increase per cent, of liquid recovered	1.1	0.3	0.7	5.4	1.0	1.3
Amount of sample for distillation, c c	590	502	503	615	505	506
Temperature of condenser bath, deg. fahr	48	48	....	46	....	....
Amount of distillate, c. c	7.0	3.0	1.5	14.0	5.8	2.7
Temperature range of distillate, deg. fahr	166–260	199–260	....	160–260	138–260	....
Amount of gasoline obtained, cubic centimeters	21.0	9.0	4.5	42.0	17.4	8.1
Amount of gasoline obtained, pints per M cu. ft.	0.44	0.19	0.08	0.888	0.368	0.171
Total pints of gasoline per M cubic feet of gas	0.71			1.427		

TABLE 4—Continued

Test No.	3			4		
Date	January 30, 1916.			January 30, 1916.		
Time	9:35 to 10:45 A. M.			1:05 to 2:25 P. M.		
Kind of oil used	Mineral Seal.			Mineral Seal.		
Specific gravity of oil, deg. Baume	35.0			35.0		
Amount of oil used, cubic centimeters	1750	1500	1500	1750	1500	1500
Pressure on absorber, lb. per sq. inch	40 lb. gauge			85 lb. gauge		
Gas rate by meter, cubic feet per hour	85			75		
Ratio, c. c. of oil to 1000 cubic feet of gas	17500	15000	15000	17500	15000	15000
Cubic feet of gas consumed	100	100	100	102	102	102
Amount of liquid recovered, c. c	1825	1555	1535	1850	1550	1545
Sp. gr. of liquid recovered, deg. Baume	35.7	35	34.8	35.4	35.2	35. 2
Temperature of liquid recovered, deg. fahr	64	68	69	68	70	70
Per cent of saturation of liquid recovered	2.6	1.0	....	2.8	1.02	0.8
Increase in c. c. of liquid recovered	75	55	35	100	50	45
Increase, per cent of liquid recovered	4.3	3.7	2.3	5.14	3.3	3
Amount of sample for distillation, c. c	608	518	512	617	516	515
Temperature of condenser bath, deg. fahr	46	....	sample lost before distillation	52	52	52
Amount of distillate, c. c	15.6	5.2		20.8	5.2	4.0
Temperature range of distillate, degrees fahr	130–260	....		120–260	130–260	....
Amount of gasoline obtained, cubic centimeters	46.8	15.6		62.4	15.6	12.0
Amount of gasoline obtained, pints per M cu. ft.	0.989	0.33		1.31	0.33	....
Total pints of gasoline per M cubic feet of gas	1.489 Estimated loss 0.17 (See previous test)			1.89		0.25

TABLE 4—Continued

Test No.	5		
Date	January 31, 1916.		
Time	8:15 to 9:37 A. M.		
Kind of oil used	Mineral Seal.		
Specific gravity of oil, deg. Baume	34.2		
Amount of oil used, cubic centimeters	1750	1500	1500
Pressure on absorber, lb. per sq. inch	110 lb. gauge		
Gas rate by meter, cubic feet per hour	....	....	....
Ratio, c. c. of oil to 1000 cubic feet of gas	17500	15000	15000
Cubic feet of gas consumed	100	100	100
Amount of liquid recovered, c. c.	1875	1575	1550
Sp. gr. of liquid recovered, deg. Baume	36.7	35.5	35.5
Temperature of liquid recovered, deg. fahr	64	66	66
Per cent saturation of liquid recovered	....	....	....
Increase in c. c. of liquid recovered	125	75	50
Increase, per cent of liquid recovered	7.15	5.0	3.3
Amount of sample for distillation, cubic centimeters	....	....	....
Temperature of condenser bath, deg. fahr	48	48	48
Amount of distillate, c. c.	21.1	1.0	0.3
Temperature range of distillate, deg. fahr	....	....	....
Amount of gasoline obtained, cubic centimeters	63.3	3.0	1.2
Amount of gasoline obtained, pints per M cubic feet	1.34	0.6	0.025
Total pints of gasoline per M cubic feet of gas	1.97		

The yield of gasoline obtained from the steam still during this test was 0.94 pints of 80 deg. Baume gasoline per 1,000 cubic feet of gas. The yield of gasoline from the refrigerator was 3.25 gallons per 130,000 cubic feet of natural gas, or 0.2 pints per 1,000 cubic feet; 0.2 plus 0.94 pints=1.14 pints total yield.

Effect of Pressure and Temperature on the Absorption of Gasoline from Natural Gas—The authors found that the yield of gasoline was considerably affected by the pressure under which the absorption was effected. This is to be expected. In one test an increase in the pressure of the gas from atmospheric to 110 lb. per square inch increased the yield from 0.7 pints to about 1.8 pints per 1,000 cubic feet of gas.

An increase in the temperature of the oil in the absorber from about 75 deg. fahr. to 85 deg. fahr. lowered the yield about 0.3 pints per 1,000 cubic feet of gas.

Cost Data—As a result of the experiments conducted to date, a much larger plant is contemplated, capable of handling about 50 million cubic feet of natural gas per day. Exact figures regarding the cost of installing such a plant cannot be given at the present time. It is believed, however, that a conservative estimate is $1.00 to $1.50 per thousand cubic feet of gas handled per day for a "plant" capable of handling 60 to 90 million cubic feet and up to $2.00 per thousand cubic feet of gas for a plant of 30 million cubic feet or less. The returns are large. At $1.00 per thousand cubic feet, a plant to handle 60 million cubic feet would cost $60,000. If only one pint of gasoline was extracted from each 1,000 cubic feet of gas per day, there would be extracted from 60 million cubic feet 7,500 gallons of gasoline. At twenty cents per gallon for gasoline, this is $1,500 per day. If natural gas sells for thirty cents per 1,000 cubic feet, the extraction of the gasoline adds about two cents per 1,000 to the selling price of the gas.

Combination Process of Absorption of Gasoline from Natural Gas by Means of Naphtha and Mineral Seal Oil— This process, heretofore described, of extracting gasoline from natural gas by absorption, consisted in first passing the natural gas through mineral seal oil and then separating the absorbed gasoline from the oil by steam distillation. This process resulted in obtaining from one gas the authors experimented with about 1.2 pints of gasoline per 1,000 cubic feet of gas, and another gas about 1.8 to 1.9 pints of gasoline. This has reference to tests made with the small absorber shown in figure 46.

In using the mineral seal oil as the absorbent, it was found that the increase in volume of the mineral seal oil after passing natural gas through it, did not correspond with the quantity of gasoline subsequently obtained from the oil by distillation. This was due to the fact that a considerable quantity of the lighter hydrocarbons were absorbed from the natural gas, increasing the volume of the mineral seal oil, but escaping as a gas when the oil was subjected to distillation to obtain the absorbed gasoline.

The loss of material appeared to be considerable, so a solution was sought that would result in obtaining this material wasted by the oil absorption and distillation process. Therefore several tests were made, using the small absorbers of the type shown in figure 46 with naphtha, specific gravity 55 deg. Baume in the first two absorbers and mineral seal oil in the third absorber. The object was to absorb as much of the gasoline as possible, including the lighter hydrocarbons, in the first two absorbers and the rest of the gasoline in the mineral seal oil. Table No. 5 shows the results of these tests.

Comments on Tests—It will be observed that the gasoline extracted from the natural gas by passing the latter through naphtha amounted to 4.86 gallons per 1,000 cubic feet of gas in the case of one test. The lowest yield was 2.70

TABLE 5

Extraction of gasoline from natural gas by passing the latter through naphtha

Test No.	1			2		
Oil or naphtha used	Naphtha	Naphtha	Mineral seal	Naphtha	Naphtha	Mineral seal
Sp. gr. of oil or naphtha, deg. Baume	53.5	53.5	32.5	55.5	55.5	34.2
Pressure on gas, lb. per sq. in.	235	235	235	230	230	230
Gas rate, cubic feet per hour	50	50	50	55	55	55
Amount of gas used, cubic feet	200	200	200	105	105	105
Oil used, c. c.	1750	1500	1500	1750	1500	1500
Oil recovered, c. c.	1950	1640	1565	1925	1569	1510
Sp. gr. of liquid recovered, deg. Baume	61.6	60.0	37.7	59.6	58.0	36.3
Temperature of liquid in absorber, deg. fahr.	27	29	26	19	19	19
Increase in liquid in absorber, c. c.	200	140	65	175	60	10
Sample of mineral seal oil for distillation	....	....	500	....	....	503
Amount of gasoline distilled from mineral seal oil, c. c.	....	....	7	....	....	2
Yield of gasoline, pints per 1000 cubic feet of gas	2.114	1.480	0.687	0.353	0.121	0.12
Total yield, pints per 1,000 cubic feet of gas		4.28			4.86	

TABLE 5—Continued

Test No.	3			4		
Oil or naphtha used	Naphtha	Naphtha	Mineral seal	Naphtha	Naphtha	Mineral seal
Sp. gr. of oil or naphtha, deg. Baume	55.5	55.5	33.9	55.5	55.5	34.2
Pressure on gas, lb. per sq. in.	235	235	235	235	235	235
Gas rate, cubic feet per hour	180	180	180	54	54	54
Amount of gas used, cubic feet	200	200	200	217	217	217
Oil used, c. c.	1750	1500	1500	1750	1500	1500
Oil recovered, c. c.	1850	1555	1600	2040	1600	1560
Sp. gr. of liquid recovered, deg. Baume	58.2	54.8	36.2	62.0	58.6	36.1
Temperature of liquid in absorber, deg. fahr.	54	54	60	28	28	26
Increase in liquid in absorber, c. c.	100	55	100	290	100	60
Sample of mineral seal oil, for distillation	.....	.....	533	.....	.....	520
Amount of gasoline distilled from mineral seal oil, c. c.	.....	.....	25	.....	.....	7
Yield of gasoline, pints per 1000 cubic feet of gas	1.06	0.58	1.06	2.92	0.97	0.21
Total yield, pints per 1000 cubic feet of gas		2.70			4.10	

TABLE 5—Continued

Test No.	5			6		
Oil or naphtha used	Naphtha	Naphtha	Mineral seal	Naphtha	Naphtha	Mineral seal
Sp. gr. of oil or naphtha, deg. Baume	55.5	55.5	34.2	55.0	55.0	34.2
Pressure on gas, lb. per sq. in.	235	235	235	235	235	235
Gas rate, cubic feet per hour	180	180	180	56	56	56
Amount of gas used, cubic feet	100	100	100	202	202	202
Oil used, c. c.	1750	1500	1500	1750	1500	1500
Oil recovered, c. c.	1810	1525	1560	2020	1595	1530
Sp. gr. of liquid recovered, deg. Baume	57.3	56.8	35.9	60.9	58.9	36.1
Temperature of liquid in absorber, deg. fahr.	60	60	66	18	18	18
Increase in liquid in absorber, c. c.	60	25	60	270	95	30
Sample of mineral seal oil for distillation			520			500
Amount of gasoline distilled from mineral seal oil, c. c.			16			5.6
Yield of gasoline, pints per 1000 cubic feet of gas	1.27	0.53	1.27	2.90	0.99	0.17
Total yield, pints per 1000 cubic feet of gas		3.07			4.06	

gallons. The increase in yield over the oil absorption and distillation method varied between 300 and 500 per cent.

In test No. 1 the specific gravity of the naphtha was raised from 53.5 deg. Baume to 61.6 deg. Baume in the first absorber and to 60 deg. Baume in the second absorber. The increase in volume of naphtha in first absorbers was 200 cc. or 11.5 per cent, and in the second absorber 140 cc. or about 9.3 per cent.

The greatest increase in volume and specific gravity of the naphtha was obtained in No. 1 absorber, No. 4 test. The specific gravity of the naphtha was raised from 55.5 deg. Baume to 62 deg. Baume, and the increase in volume was 290 cc. or about 16.6 per cent.

The vapor pressure of the resulting naphtha in No. 1 absorber, No. 4 test, was 5 pounds per square inch at 100 deg. fahr. and the evaporation or weathering loss was 5 per cent in 24 hours. During this weathering test the temperature of the gasoline raised from 54 deg. fahr. at the start to 64 deg. fahr. at the finish. The temperature of the room changed from 56 deg. fahr. to 64 deg. fahr. The temperature of the naphtha had much influence on the results of the tests. The highest yield was that shown in No. 2 test where the temperature of the naphtha was 19 deg. fahr. This test was conducted in the open air on a cold winter day. However, even at a temperature of 60 deg. fahr. a yield as high as 3.07 pints of gasoline per 1,000 cubic feet of gas was obtained. Test No. 6 was instructive in that the vapor pressure of the resulting naphtha in No. 1 and No. 2 absorbers was 14 pounds per square inch at 100 deg. fahr. In other words, its vapor pressure exceeded that prescribed for gasoline to be shipped in tank cars.

In summing up the use of naphtha as an absorbent for extracting gasoline from natural gas, it can be stated that a greater yield can be obtained than by using the oil absorption and distillation process, as much as 300 per cent

greater than ordinary temperatures and 400 to 500 per cent greater if temperatures as low as 18 deg. to 19 deg. fahr. are employed. A further advantage lies in the fact that the resulting naphtha with its absorbed gasoline does not have to be subjected to distillation to obtain gasoline but can be sold as prepared.

An objection to it lies in the fact that a large amount of naphtha would have to be handled in large scale operations. Mineral seal oil can be used over and over again with but slight loss while the naphtha would have to be constantly received.

The greatest increase in volume of the naphtha was 16.6 per cent in No. 4 test. This amounts to about 6 to 7 times as much naphtha as gasoline, i. e., for each tank of gasoline extracted from the natural gas there would be needed 6 or 7 tanks of naphtha. One cannot absorb too much gasoline in the naphtha else the vapor pressure of the resulting mixture exceeds the limit (10 pounds per square inch at 100 deg. fahr.) set for the transportation of gasoline in tank cars.

If an absorption gasoline plant could be located at or close to a refinery where a large supply of naphtha was available, the difficulty and trouble of transporting large quantities of naphtha into the absorption plant would be largely overcome, but in most, and perhaps all cases, this is not feasible.

One can look at the problem in the following way:

By the oil absorption process there is obtained one third as much gasoline as by the naphtha process. One tank car (10,000 gallons) of the absorption process gasoline sells for about 20 cents per gallon, or $2,000. (This figure, however, will vary.) Three tank cars will sell for $6,000, or an increase of $4,000. But in order to secure this increase of $4,000, about 7 tank cars of naphtha would have to be brought into the absorption plant, i. e., at least seven times as much naphtha would have to be handled as of gasoline extracted."

Testing "Lean" Natural Gas for Gasoline Content—In testing this gas for gasoline content the same procedure as described on page 50, under First and Second paragraphs is followed, except the gas samples are taken from the pipe line at different times during the day. With high pressure gas in pipe lines one would be able to obtain an average sample from all wells feeding the lines, eliminating the necessity of testing each individual well or group of wells.

In the operation of testing, a portable testing outfit, consisting of absorber, meter, and a small still is used, in place of the small compressor, etc. The outfit is installed on a high pressure gas line and the gas allowed to pass into the atmosphere after being treated. Fig. 46 illustrates the outfit.

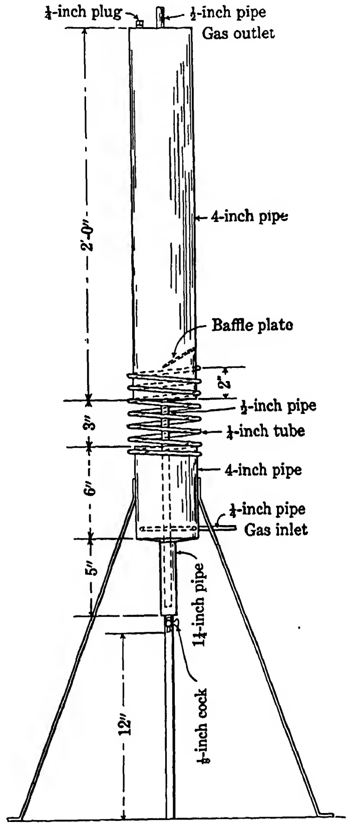


Fig. 46—TESTING APPARATUS FOR DETERMINING GASOLINE CONTENT IN "LEAN" NATURAL GAS BY THE ABSORPTION PROCESS. Designed by G. A. Burrell and P. M. Biddison

The Determination of the Gasoline Content of "Dry" Natural Gas—Natural gas is popularly classified as "wet" natural gas, meaning casinghead gas suitable for the extraction of gasoline by compression and condensation methods, and as "lean" natural gas meaning natural gas used in cities

and factories. This latter although producing some condensate in pipe lines, is unsuited for the extraction of gasoline by the above methods.

Much of this gas, however, can be treated for gasoline extraction, by the new absorption method, hence there follows a scheme for testing these "lean" natural gases to determine their gasoline content.

This apparatus consists of an absorber A, a meter B, a distillation flask D, with condenser C, and a graduated cylinder E.

The absorber A is made of iron pipe and welded to guard against leakage and to withstand a pressure of 500 or more pounds per square inch.

To start a test, about 2,000 c. c. of mineral seal oil, accurately measured, are poured into the absorber A through the opening H. The short pipe nipple at H is temporarily removed for this purpose. The meter B should be capable of measuring from one to 300 cubic feet of gas accurately. Gas connection is made at K and 100 cubic feet of natural gas passed through the absorber at the rate of 100 cubic feet per hour. The gas entering the absorber bubbles up through the mineral seal oil, the latter absorbing the gasoline. The gas passes out of the absorber at M and through the meter. A pressure of 100 to 300 pounds per square inch is maintained on the gas. The pressure can be read by means of the gauge N and regulated by adjusting the valve P. The absorption process is one that works best at these pressures, and usually natural gas to be treated by the absorption method is under these or higher pressures.

After the requisite amount of natural gas has passed through the absorber, the gas supply is shut off, the pressure released, and 500 c. c. of oil drawn from the absorber and transferred to the distilling flask D. This flask is connected with a condenser C and provided with a thermometer R. This thermometer should read up to 400 deg. fahr.

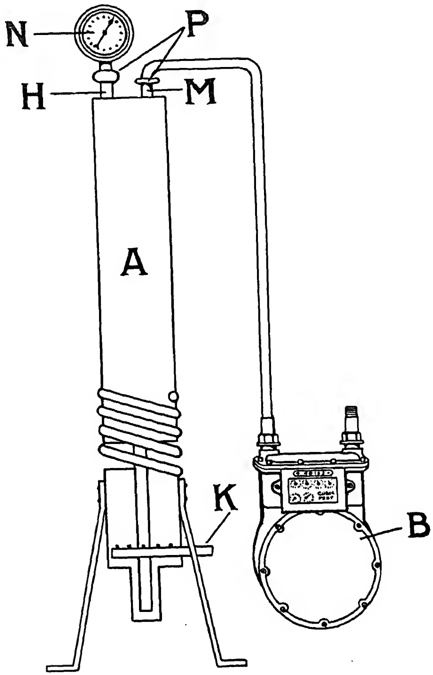


Fig. 47—FIELD ABSORPTION APPARATUS FOR DETERMINING GASOLINE CONTENT OF "LEAN" NATURAL GAS
Designed by G. A. Burrell and P. M. Biddison

Index

A = Absorber.

B = Gas meter.

H = Opening for oil.

K = Gas connection.

M = Gas outlet.

N = 500 lb. spring gauge.

P = High pressure wheel valves.

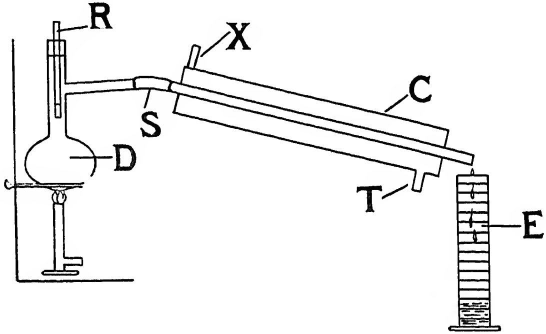


Fig. 48—DISTILLATION APPARATUS

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C Condensor.

D Distilling flask.

E Receiver.

R Thermometer.

X Water inlet.

T Water outlet.

The flask is heated, slowly at first, and the gasoline that is driven out of the oil collected in the graduated cylinder E. The gasoline will start to drop into the receiver E at a temperature of about 80 deg. fahr., and will usually have all distilled at a temperature not higher than 330 deg. fahr. The mineral seal oil itself starts to distill at a temperature of about 375 deg. to 400 deg. fahr., hence the temperature of the oil must not be raised that high.

The distillation apparatus is connected as shown. The flask D is connected to the condenser C by means of the rubber tubing S. Water for the condenser is used to cool the hot gasoline vapor from the still and make it condense, and passes into the condenser at T and out at X.

The method of calculating the results of a test is shown by means of the following example.

Calculation of Amount of Gasoline Extracted from Natural Gas by Means of the Absorption Method

Amount of oil used . . . . 2000 c. c.
Amount of gas used . . . . 100 cu. ft.
Amount of oil taken for distillation . 500 c. c.
Amount of gasoline extracted . . . . . 40 c. c.
Amount of gasoline per 1,000 cubic feet of gas. . .4 by 40 by 10=1600 c. c. or 3.4 pints. There are 473 c. c. in one pint).

This small field test is a duplicate on a small scale of the actual big scale operations and gives very reliable results. The absorption method, even although a small yield of gasoline per 1,000 cubic feet of gas is obtained becomes valuable when several or many million cubic feet of gas per day are available.

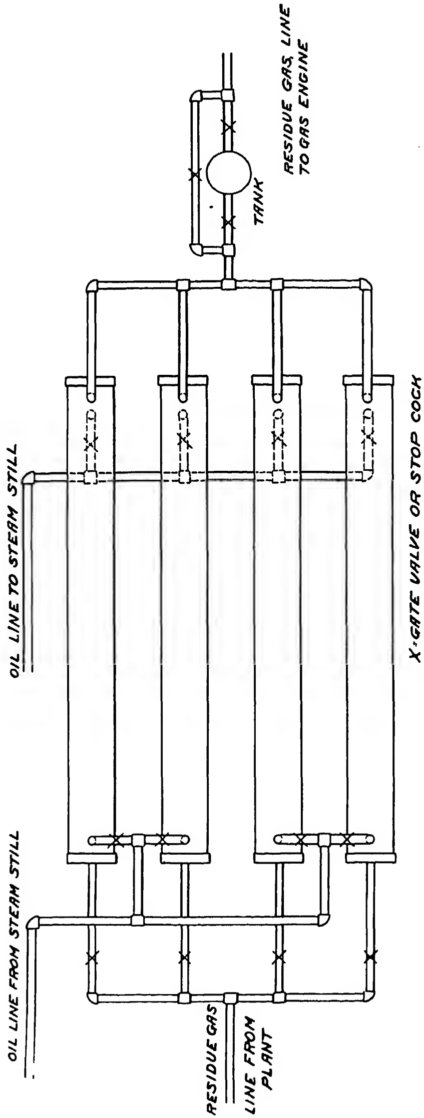

Fig. 49—PLAN OF ABSORPTION SYSTEM AS APPLIED TO RESIDUE GAS

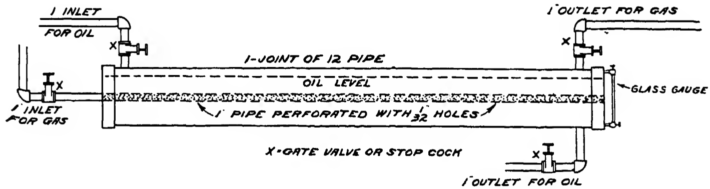

Fig. 50—PLAN OF A SINGLE SECTION OF AN ABSORPTION METHOD PLANT AS APPLIED TO RESIDUE GAS

Absorption of Gasoline from Casinghead Gas—The process of extracting gasoline from "lean" natural gas or from gas having a gravity of less than 0.80 differs materially from the compressor process. Primarily to extract gasoline from this gas profitably, it is necessary to treat a far greater quantity of gas, as the amount of gasoline obtained runs from only one tenth of a gallon up to possibly one and one half gallons per 1,000 cubic feet. It would not be a profitable proposition to extract so small a quantity of gasoline from one thousand cubic feet of gas by the compression method, but as there is so little expense incurred through the extracting of gasoline by the absorption process it has proven to be a great success.

There are two kinds of gas treated by this process—the well known casinghead gas which always flows from the well at a low pressure, and the natural gas which flows from gas wells at a high pressure.

With the first mentioned gas the equipment requires a high pressure blower, absorption coils or tanks and a steam still.

In some instances high pressure blowers are used on a group of leases, in the same manner that the vacuum pump is used with the compression method, to place a vacuum on the wells and to overcome friction in the pipe line between the vacuum station or booster and the main gasoline plant.

The gas is forced through the absorption coils or tanks with the aid of the high pressure blower, at a pressure of three or four pounds. In passing through the coils or tanks, the gas comes in contact with the oil or absorption medium, agitates it, and the gasoline content in the gas is taken up by the oil or medium. The success of the operation is dependent upon all of the gas coming in contact with all of the oil, whereupon the absorption takes place.

The oil is drawn off and treated in a steam still the same as at an oil refinery, and is used over and over again.

The oil generally used is a torch or mineral seal oil. Any oil is suitable that has previously had the higher hydrocarbons extracted. A distillate of 35 deg. Baume gravity is found to be very successful as an absorbent.

After the gas passes through the absorbing coils or tanks it is little effected and looses practically no pressure. The outfit required is far cheaper than the compression method.

With the second mentioned gas—"lean" natural gas—the absorption process is the same except that the pressure of the gas is higher and a stronger equipment is required than when treating casinghead gas.

On account of the high pressure which causes greater agitation in the oil, larger sized coils or tanks are required.

It is rapidly becoming an established business to install absorption plants on large gas lines supplying towns and cities. At this writing there is one large company installing plants in Ohio to treat one hundred million cubic feet of "lean" natural gas daily. In this instance the amount of gasoline obtained from a thousand cubic feet of gas varies from one to two pints per thousand cubic feet of gas.

PART EIGHT

Transportation of Gasoline

Shipping Gasoline—Steel drums of the very best type manufactured should be used and must stand a pressure of forty pounds per square inch without any leaks whatever. A fifty-five gallon drum should weigh not more than seventy pounds without hoops and a one hundred and ten gallon drum should weigh not less than one hundred and thirty pounds without hoops.

If a drum, such as is used for shipping gasoline and high distillates, filled with 64 deg. Baume gasoline is allowed to stand in the sun with the thermometer registering 95 deg. fahr. with a pressure gauge attached, it will show that the heat has caused a gas pressure of twenty nine and one half pounds. For the purpose of transporting gasoline, special drums have been designed to withstand over eighty pounds pressure.

Do not use wooden plugs. Metal plugs should be close fitting, using a gasket of asbestos.

Glycerine drums are not satisfactory holders of gasoline.

Drums should not be filled full, but only to within about two inches of the top, to allow for expansion.

High gravity gasoline lies dormant when cold, but as its temperature rises above its boiling point it begins to agitate or boil, creating a vapor tension in the tank or drum which raises the boiling point to that corresponding to the increased vapor pressure, thus maintaining a condition of equilibrium.

It is better to ship to a colder climate than to a warmer one. This lessens the liability for losses due to boiling from increased temperature.

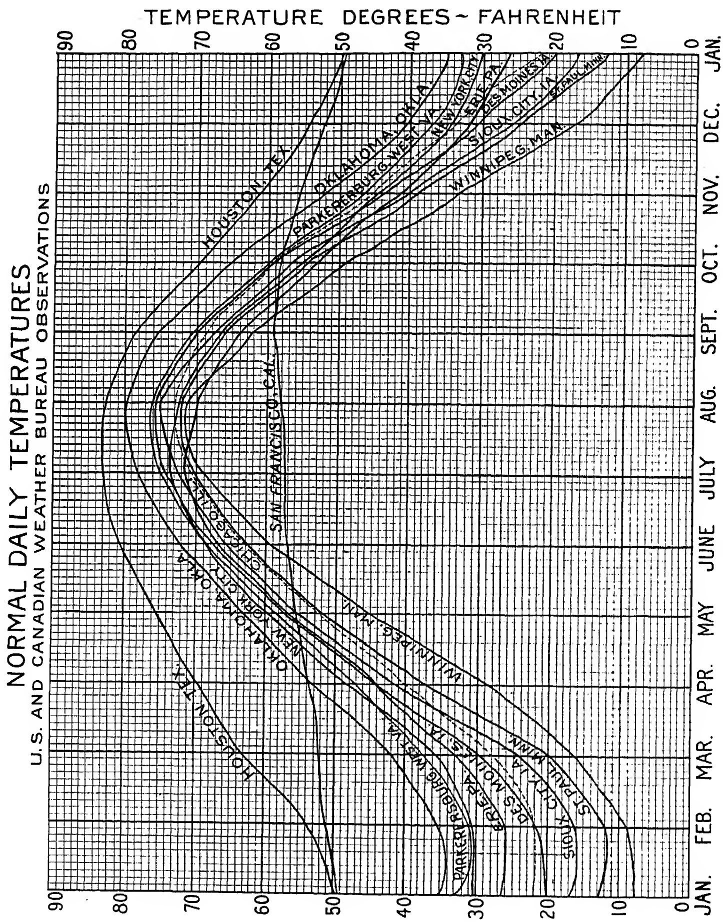
NORMAL DAILY TEMPERATURES
U.S. AND CANADIAN WEATHER BUREAU OBSERVATIONS
TEMPERATURE DEGREES ~ FAHRENHEIT
90
80
70
60
50
40
30
20
10
0
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
HOUSTON, TEX.
OKLAHOMA, OKLA.
PARKERSBURG, WEST VA.
NEW YORK CITY
ERIE, PA.
DES MOINES, IA.
SIOUX CITY, IA.
ST. PAUL, MINN.
WINNIPEG, MAN.
SAN FRANCISCO, CAL.

Fig. 51

The following simple rules have been found approximately true for Sistersville casinghead gasoline and they are probably fairly accurate for Oklahoma and other casinghead gasolines. Neither the vapor tension rise nor the evaporation loss are regular, but vary more or less with the temperature:

Rule of Thumb for Vapor Tension

1st—Vapor tension rises or falls about 0.28 pounds for each degree rise or fall of the boiling point.

2nd—64 deg. fahr. is approximate boiling point for 10 pound vapor tension liquid tested at 100 deg. fahr.

Example:—At what temperature will 7 pound vapor tension liquid boil in the cars? As the vapor tension will fall about 0.28 pounds per degree, a drop of 25 degrees will remove all pressure. Then the boiling point will be 75 deg. fahr. (or 25 degrees below 100) the point at which the vapor tension was seven pounds.

Rule of Thumb for Evaporation Losses

1st—Natural gasoline loses about 3.5 per cent for the first ten degrees rise in temperature above its boiling point, and about 7 per cent for each 10 degrees thereafter.

Example:—A—What would we lose on raw gasoline we received at 40 deg. fahr. and sent out at a temperature of 70 deg.?

The first ten deg. equals 3.5 per cent loss and the next 20 deg. 14 per cent, so the loss would be approximately 17.5 per cent altogether.

NORMAL DAILY TEMPERATURES

Parkersburg, W. Va.

U. S. Government readings

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	32	32	37	48	58	68	74	75	70	61	48	39
2	32	32	38	48	59	68	75	75	70	60	48	38
3	32	32	38	49	59	68	75	75	70	60	47	38
4	32	32	38	49	60	69	75	75	70	60	47	38
5	32	32	39	49	60	69	75	75	69	59	47	38
6	32	32	39	50	60	69	75	75	69	59	46	37
7	31	32	39	50	60	70	75	75	69	58	46	37
8	31	32	40	50	61	70	75	75	68	58	46	37
9	31	33	40	51	61	70	75	75	68	58	45	37
10	31	33	40	51	62	70	75	74	68	57	45	37
11	31	33	41	51	62	71	76	74	68	57	44	36
12	31	33	41	52	62	71	76	74	67	56	44	36
13	31	33	41	52	62	71	76	74	67	56	44	36
14	31	34	42	52	63	71	76	74	67	55	44	36
15	31	34	42	53	63	72	76	74	66	55	43	36
16	31	34	42	53	63	72	76	74	66	54	43	35
17	31	34	43	53	64	72	76	73	66	54	43	35
18	31	34	43	54	64	72	76	73	66	54	42	35
19	31	35	43	54	64	72	76	73	65	53	42	34
20	31	35	44	54	65	73	76	73	65	53	42	34
21	31	35	44	55	65	73	76	73	65	52	41	34
22	31	35	44	55	65	73	76	72	64	52	41	34
23	31	36	45	56	66	73	76	72	64	52	41	34
24	31	36	45	56	66	73	76	72	64	51	40	33
25	31	36	45	56	66	74	76	72	63	51	40	33
26	31	36	46	57	66	74	76	72	63	50	40	33
27	31	37	46	57	66	74	76	71	62	50	40	33
28	32	37	46	58	67	74	76	71	62	50	40	32
29	32	....	47	58	67	74	76	71	62	49	39	32
30	32	....	47	58	67	74	75	71	61	49	39	32
31	32	....	47	.....	68	.....	75	70	.....	49	.....	32

This table shows the normal daily temperatures and boiling points which may be expected for West Virginia gasoline.

NORMAL DAILY TEMPERATURES

Oklahoma, Okla.

U. S. Government readings

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	35	36	43	55	64	72	79	80	76	68	54	42
2	35	36	44	55	64	73	79	80	76	67	54	42
3	35	36	44	56	65	73	79	80	75	67	53	42
4	35	36	44	56	65	73	79	80	75	66	52	42
5	35	36	45	56	65	74	79	80	75	66	52	41
6	35	36	45	57	65	74	79	80	75	66	52	41
7	35	36	46	57	66	74	79	80	74	65	51	41
8	35	37	46	57	66	74	80	80	74	65	50	41
9	35	37	46	58	66	74	80	80	74	64	50	40
10	34	37	47	58	66	75	80	80	74	64	50	40
11	34	37	47	58	67	75	80	79	74	64	49	40
12	34	37	48	59	67	75	80	79	73	63	49	40
13	34	38	48	59	67	75	80	79	73	63	49	40
14	34	38	48	59	68	76	80	79	73	62	48	39
15	34	38	49	60	68	76	80	79	72	62	48	39
16	34	39	49	60	68	76	80	79	72	61	47	39
17	34	39	50	60	69	76	80	79	72	61	47	38
18	35	39	50	60	69	76	80	78	72	61	47	38
19	35	39	50	61	69	77	80	78	71	60	46	38
20	35	40	51	61	69	77	80	78	71	60	46	38
21	35	40	51	61	70	77	80	78	70	59	46	37
22	35	40	52	62	70	77	80	78	70	59	45	37
23	35	41	52	62	70	77	80	78	70	58	45	37
24	35	41	53	62	70	78	80	78	70	58	45	36
25	35	41	53	62	71	78	80	77	69	57	44	36
26	35	42	53	63	71	78	80	77	69	57	44	36
27	35	42	54	63	71	78	80	77	69	56	44	36
28	35	43	54	63	72	78	80	77	68	56	43	36
29	35	....	54	64	72	78	80	76	68	55	43	36
30	35	....	54	64	72	78	80	76	68	55	43	35
31	35	....	55	.....	72	78	80	76	.....	54	.....	35

This table shows the temperatures and boiling points well weathered gasoline may be expected to show in Oklahoma.

PRESSURES GENERATED BY HEATING GASOLINE AND CONFINED LIQUEFIED NATURAL GAS

(*By G. A. Burrell*)

Temperature		Pressures Generated by—			
		Refinery gasoline (80 deg. Baume)	Natural Gasoline Obtained at—		
			50 pounds pressure	250 pounds pressure	400 pounds pressure
deg. cent.	*deg. fahr.*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	32	0	..	107	360
5	41	0	9	117	375
10	50	0	12	130	398
15	59	0	16	144	423
20	68	3	20	154	453
25	77	5	25	175	482
30	86	10	30	193	510
35	95	16	34	210	545
40	104	26	40	231	585
45	113	41	46	251	630
50	122	92	52	275	690
55	131	150	58	...	755
60	140	..	65	...	...

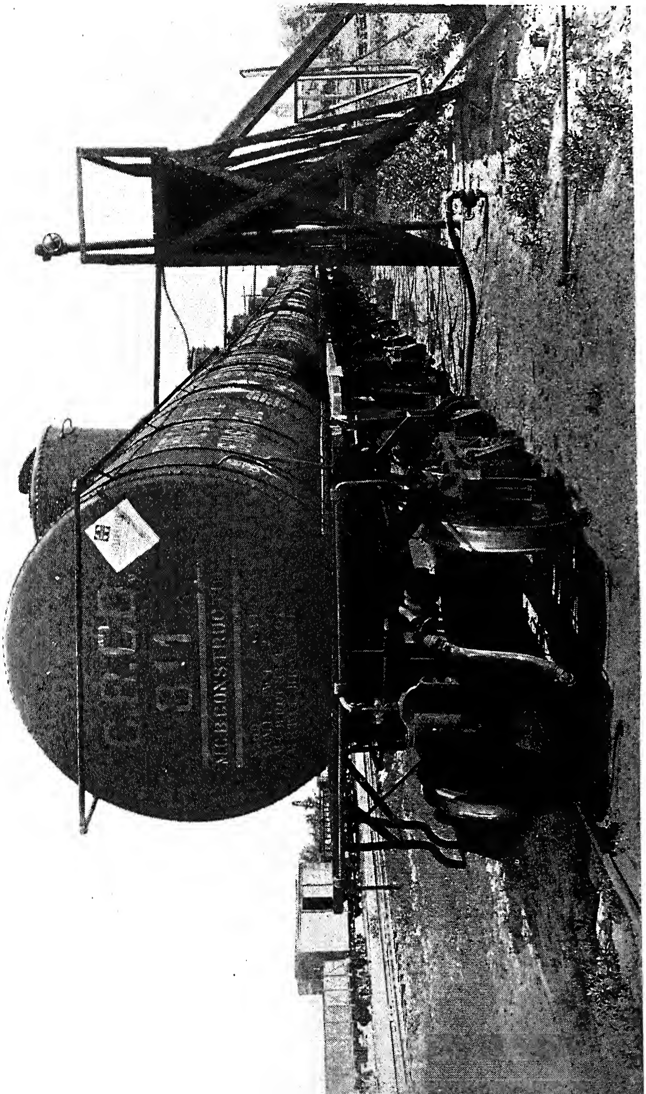

Fig. 52—GASOLINE LOADING RACK AT KIEFER, OKLA. FORMERLY USED FOR LOADING OIL

Tank Cars—Tank cars of one kind and another have been used on American railroads for nearly forty years. Originally they were merely tubs or vats loaded on flat cars. Horizontal tanks came later and then followed the modern type of tank car.

Insulated Tank Cars—This design of tank car has many advantages over the old common tank car. The great advantage is that the insulation surrounding the tank keeps the temperature of the contents from being affected by the atmospheric temperature. This permits shipping higher gravity gasoline with far less loss than with the old design car. As the liquid is kept at an even temperature, there is also less liability of the gasoline boiling on a hot day, causing the safety valves to blow and allowing the gasoline and gas to escape into the atmosphere.

Description of Insulated Tank Car—The inner tank is made of extra heavy material, tested and made perfectly tight at 100 lb. pressure. Over this, heavy paper is wrapped and secured to prevent the sweating of the tank. Then 2-inches of the best quality of insulating material is carefully applied with joints broken. Another layer of water-proof paper is wrapped around the insulation and over this another steel tank of lighter material is built. The tank heads and dome being similarly insulated. The tanks are designed to be unloaded either by gravity through the bottom outlet or by air pressure by pipes extending through the dome.

Tanks are anchored to the underframe without the use of head blocks as shown in figure 53.

To Find the Gauge of Tanks—Multiply the square of the diameter of the tank by .7854; multiply the result by the length of the tank in inches, divide by 231 and the result is the capacity of the tank in U. S. gallons. If the tank has curved ends (as all car tanks have) add to the length two-thirds of the dish at each end.

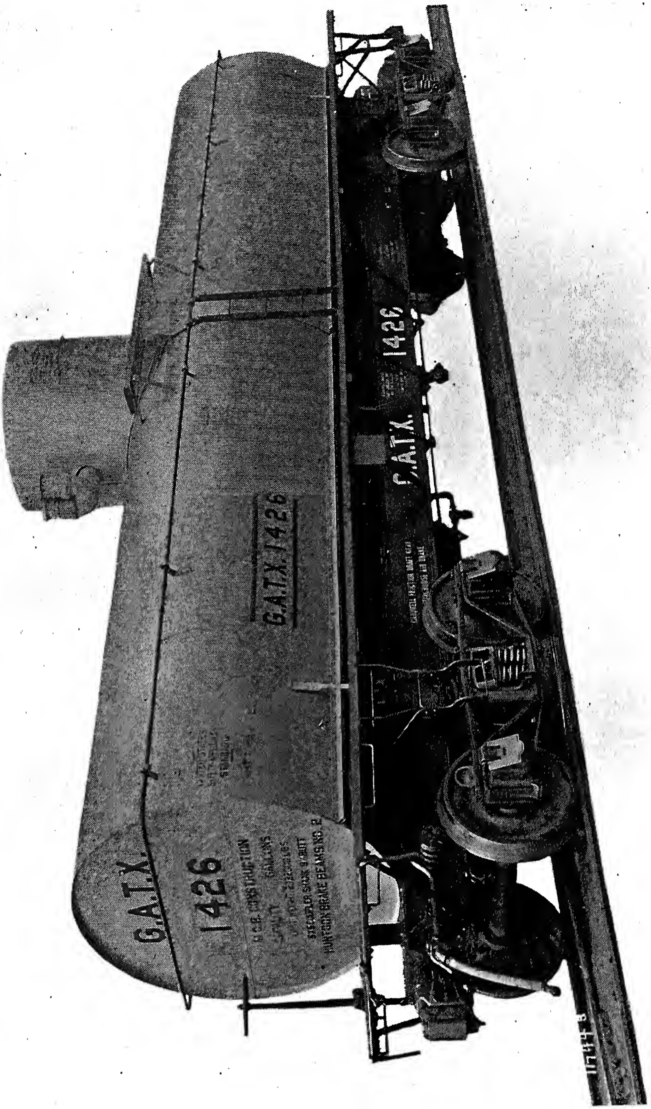

Fig. 53—INSULATED TANK CAR

TANK CAR OUTAGE TABLE

Showing Capacity of an 8,000 gallon Tank Car at Different Levels

Wet Reading ft.	in.	Contents U. S. gal.	Wet Reading ft.	in.	Contents U. S. gal.	Wet Reading ft.	in.	Contents U. S. gal.
	1	20.4	3	4	4160.	**6	7	8084.
	2	63.7	3	5	4293.	6	8	8093.8
	3	102.	3	6	4424.	6	9	8103.74
	4	157.	3	7	4554.	6	10	8113.66
	5	218.	3	8	4684.	6	11	8123.57
	6	285.	3	9	4814.	7	0	8133.49
	7	356.5	3	10	4945.	7	1	8143.4
	8	434.6	3	11	5073.	7	2	8153.32
	9	516.7	4	0	5201.	7	3	8163.23
	10	602.	4	1	5330.	7	4	8173.14
	11	692.2	4	2	5456.	7	5	8183.06
1	0	785.5	4	3	5582.	7	6	8192.97
1	1	881.3	4	4	5705.	7	7	8202.89
1	2	981.1	4	5	5829.	7	8	8213.05
1	3	1082.	4	6	5950.	7	9	8223.97
1	4	1187.	4	7	6071.	7	10	8234.88
1	5	1296.	4	8	6191.	7	11	8245.04
1	6	1405.	4	9	6308.	8	0	8254.96
1	7	1518.	4	10	6424.	8	1	8264.87
1	8	1630.	4	11	6536.	8	2	8274.79
1	9	1746.	5	0	6649.	8	3	8284.7
1	10	1863.	5	1	6758.	8	4	8294.62
1	11	1983.	5	2	6867.	8	5	8304.53
2	0	2104.	5	3	6972.	8	6	8314.45
2	1	2225.	5	4	7073.	8	7	8324.36
2	2	2349.	5	5	7173.	8	8	8334.28
2	3	2472.	5	6	7269.	8	9	8342.29
2	4	2598.	5	7	7362.	8	10	8346.98
2	5	2724.	5	8	7452.08	8	11	8349.48
2	6	2853.	5	9	7538.32	9	0	8351.98
2	7	2981.	5	10	7620.07	9	1	8354.48
2	8	3109.	5	11	7699.34	9	2	8356.98
2	9	3240.	6	0	7771.36	9	3	8359.49
2	10	3370.	6	1	7839.86	9	4	8361.49
2	11	3500.	6	2	7902.96	9	5	8362.70
3	0	3630.	6	3	7960.76	9	6	8363.31
3	1	3761.	6	4	8002.86	9	7	8363.93
3	2	3894.	6	5	8051.24	9	8	8364.54
3	3	4027.	6	6	8074.			

**Denotes top of tank shell (inside)

TANK CAR OUTAGE TABLE

Calculated from 0.25 inch to 5 inches Out of Shell, at 60 deg. fahr. Capacity of Car in Gallons at 60 deg. fahr.*

Inches	4231 gallons	6000 gallons	6641 gallons	7000 gallons	8087 gallons	8102 gallons	8505 gallons	10000 gallons
0.25	3	4	4	4	5	5	5	6
0.5	6	8	8	8	10	10	10	12
0.75	9	13	13	13	16	16	17	19
1	13	18	18	18	23	23	25	26
1.25	18	24	25	25	31	31	33	36
1.5	23	31	33	33	39	39	45	46
1.75	29	38	41	41	48	48	56	58
2	35	46	49	50	58	58	67	71
2.25	41	54	58	59	69	69	79	84
2.5	48	63	68	69	80	80	92	98
2.75	55	72	78	79	91	91	105	111
3	63	82	88	90	103	103	119	125
3.25	71	92	99	101	115	115	133	140
3.5	79	103	110	113	128	128	148	156
3.75	87	114	123	125	141	141	163	171
4	96	125	134	137	154	154	178	186
4.25	105	136	146	150	167	167	194	203
4.5	114	148	159	163	181	181	211	220
4.75	123	160	172	176	195	195	228	237
5	133	173	186	190	210	210	244	254

*Courtesy of Phoenix Refining Co.

Sealing Tank Cars—In shipping gasoline in tank cars, it is advisable to affix a wire seal or lock on the dome cover. It has been found that while loaded tank cars are enroute to destination, the dome cover is removed and considerable quantities of gasoline stolen. While the monetary loss may be considerable, the liability of an explosion from lighted lanterns endangering public safety and property is far greater.

Prevention of Fires and Explosions from Blowing Safety Valves on Tank Cars—Many disastrous fires and explosions have occurred indirectly and directly from blowing safety valves on tank cars filled with gasoline. Safety valves are set at 25 lb. When the pressure within the tank exceeds 25 lb. the safety valves "blow off" and permit the gasoline gas which generally is accompanied with a gasoline spray, to flow into the atmosphere. The gas being heavier than air will follow the ground. Whenever a safety valve is blowing, the first thing to be done is to turn a stream of water on the car. This cools the shell and generally lessens the boiling, thus decreasing the pressure within. If it is not possible to use the stream of water, wet blankets can be thrown over the car and water thrown on the blankets from pails.

Loaded tank cars should always be set in shady spots if possible.

Insulated tank cars greatly lessen the liability of high temperatures even on hot days, which condition creates boiling.

Care of Tank Cars—The tank may wear on the head blocks, allowing tank to shift. This will become worse rapidly and may result in breaking off the outlet pipe. Wide solid oak shims should be carefully driven in between the head block and the steel head block plate whenever there is a space between the head block and the tank head.

The tank bands may become loose as the tank settles on the slabbing. They can easily be tightened up and this should be carefully looked after.

Safety valves will sometimes work loose from the elbow. Where vent valves are used they will sometimes work out. Keep them firmly screwed down.

Before loading a tank always examine the interior. Open the outlet valve and wipe it and the valve seat with a cloth or waste to remove any sediment that might prevent the valve closing tightly.

The valve rod is attached to the valve by a bolt and nut. The continual pounding and jarring may cause the bolt to break or the nut to come off. This should be carefully looked after and the bolt replaced as often as necessary. Otherwise you may have to pump out a tank because you cannot open the valve.

At the upper end of the valve rod of most tanks there is a strong spring to keep the valve shut. This spring works upon a collar which is secured to the valve rod by a set screw. All these parts should be inspected frequently to see that the nut and collar do not work loose or the force of the spring weaken. By means of the collar and set screw the spring may be tightened as much as desired.

Heater pipes are secured to the saddles by means of bars bolted down. Should the nuts work loose the coils may shift and break. Have the coils inspected each trip and the nuts tightened if necessary.

Always close the outlet valve before replacing cap on the discharge pipe. This is especially necessary in freezing weather, as otherwise the outlet extension pipe may fill up from the drainings and freezing break the pipe. In removing the cap for unloading in cold weather never strike the cap or nozzle with a hammer or steel bar, especially in cold weather.

When there is a stop cock on the outlet extension they are sometimes hard to open. Do not use too great force to open the cock as this is a severe strain on the outlet pipe. Loosen the nut on the opposite side of the cock and tap it with a mallet. This will enable you to open it easily.

Dome lids and outlet caps are frequently lost in transit on account of the failure of those unloading cars to see that these are properly secured to the car by chains and that they are firmly screwed down before the car goes out. This means delay and expense in replacing missing parts at the next loading place. Never allow a car to go out with the outlet cap hanging but always screw it and the dome lid into place.

Demurrage Rules on Tank Cars — Railroads charge the customary demurrage on privately owned cars except when cars are on the private tracks of the car owners. This decision was made by the Interstate Commerce Commission Nov. 14, 1908. In connection with this ruling they also defined a "private track" as one "outside the carrier's right of way, and of which the railroad does not own the roadbed, rails, ties or right of way." The commission further decided on the same date that "a private car owned by one shipper and used with his consent by another shipper is not a 'private car,' as that phrase is defined by the commission in the matter of demurrage charges." This last restriction, however, does not apply in the case of cars owned by a car company and leased to a shipper.

By the foregoing is meant that when a privately owned tank car is shipped to a customer, even though such customer owns his own switching tracks (ties, rails and roadbed) the railroad will charge demurrage for any time over

the customary allowance. In other words whenever a privately owned tank car leaves the car owner's private track it is considered in service.

FREIGHT RATES C/S OIL IN BBL. AND TANKS

Cents per 100 lb.	Oil per Gallon		Cents per 100 lb.	Oil per Gallon	
	Bbl.	Tanks		Bbl.	Tanks
5	0.45	0.375	28	2.52	2.100
6	0.54	0.450	29	2.61	2.175
7	0.63	0.525	30	2.70	2.250
8	0.72	0.600	31	2.79	2.325
9	0.81	0.675	32	2.88	2.400
10	0.90	0.750	33	2.97	2.475
11	0.99	0.825	34	3.06	2.550
12	1.08	0.900	35	3.15	2.625
13	1.17	0.975	36	3.24	2.700
14	1.26	1.050	37	3.33	2.775
15	1.35	1.125	38	3.42	2.850
16	1.44	1.200	39	3.51	2.925
17	1.53	1.275	40	3.60	3.000
18	1.62	1.350	41	3.69	3.075
19	1.71	1.425	42	3.78	3.150
20	1.80	1.500	43	3.87	3.225
21	1.89	1.575	44	3.96	3.300
22	1.98	1.650	45	4.05	3.375
23	2.07	1.725	46	4.14	3.450
24	2.10	1.800	47	4.23	3.525
25	2.25	1.875	48	4.32	3.600
26	2.34	1.950	49	4.41	3.675
27	2.43	2.025	50	4.50	3.750

Limit of Load—Under the rules formerly in force the railroads allowed cars to be loaded according to the size of car journals, 10 per cent of overloading beyond the published limit being permitted. By a new rule adopted by the Master Car Builders' Association and taking effect September 1st, 1909, the total weight of car and contents is taken into account. The rule prescribes the following "limit weights" for cars:

Size Journals	Wheel Seat	Axle Center	Limit wei of car and conte
$5\frac{1}{2}$ x 10 in.	$6\frac{3}{4}$ in.	$5\frac{7}{8}$ in.	161,00
5 x 9	$6\frac{1}{4}$	$5\frac{5}{16}$	132,00
$4\frac{1}{4}$ x 8	$5\frac{5}{8}$	$4\frac{7}{8}$	112,00

By this rule there is a decided advantage in using s cars of improved design where all superfluous and use dead weight is eliminated.

Mileage Rules of Railroads—Railroads allow t fourths of one cent per mile run on both loaded and em movements of tank cars. Private car owners are requ to furnish printed postal cards to the railroads for rep ing deliveries to connecting lines and for reporting mil earnings.

Practically all railroads follow the rule of handling en tank cars free, under orders of owners. Empty mil must, however, be equalized by loaded mileage, or paic later at tariff rates. The general rule is to furnish pri car owners with a statement of their loaded and en mileage once a year. The car owner is then allowec months additional to equalize any excess empty mile If this is not done the railroad will collect for the e empty mileage at tariff rate.

If the loaded mileage exceeds the empty mileage balance is carried forward as a "credit" to the next pe

The rate charged by railroads for hauling empty cars varies, according to territory, from ten cents per west of the Mississippi river to four cents per mile in Ce and Eastern territory.

New, or newly acquired cars, moving empty from s where built to owners, or from place of purchase, mus billed with freight charges to the owner or lessee.

Rules of the Interstate Commerce Commission—The final rules of the Interstate Commerce Commission regarding the shipment of natural gas gasoline are presented below:

Regulations for the Transportation on Railroads of Natural Gas Gasoline*—Casinghead or natural gas gasoline, blended or unblended, and with vapor tension not exceeding 10 lb. per square inch, may be shipped as gasoline:

(1) In metal drums complying with I. C. C. Shipping Container Specification No. 5; or—

(2) In 60 lb. tested ordinary tank cars, provided such cars have valves set to 25 lb. and the dome covers are made "fool-proof" by one of the methods approved by the Master Car Builders' Association, and provided the dome cover and dome bear the special white placards cautioning employes not to remove dome cover while pressure exists.

Casinghead gas or natural gas gasoline, blended or unblended, with vapor tension above 10 lb. per square inch and not exceeding 15 lb. per square inch, must be described as Liquefied Petroleum Gas, and may be shipped:

(1) In the special insulated tank cars approved by the Master Car Builders' Association; or—

(2) In metal barrels complying with I. C. C. Shipping Container Specification No. 5 and not exceeding 55 gallons capacity.

Casinghead or natural gas gasoline, blended or unblended, with vapor tension, exceeding 15 lb. per square inch and not exceeding 25 lb. per square inch, must be described as Liquefied Petroleum Gas and can only be shipped in metal drums complying with I. C. C. Shipping Container Specification No. 5 and not exceeding 55 gallons capacity.

* From "Regulations of the Interstate Commerce Commission for the Transportation of Explosives and Other Dangerous Articles by Freight and by Express and Specifications for Shipping Containers," published by the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, in January, 1912, pp. 72, 143, 144 and 145. Effective May 15, 1916.

Casinghead or natural gas gasoline, blended or unblended, with vapor tension exceeding 25 lb. per square inch, must be described as Liquefied Petroleum Gas and can only be shipped in steel cylinders as prescribed for compressed gases (paragraphs 1861 to 1863.)

The amended regulation becomes effective not later than May 15, 1916, at all points where casinghead gasoline is produced and shipped.

By January 1, 1917, all tank cars used for the shipment of any inflammable liquid with flash point below 20 deg. (which includes refinery gasoline, benzine or naphtha, carbon bisulphide, gas drips, etc.), must be equipped with the "fool-proof" dome covers and must have their valves set at 25 lb.

Only such cars as carry casinghead or natural gas gasoline, blended or unblended, must have the special dome placards, and it will be noted that for such cars the shipping order and billing accompanying the car must bear thereon an endorsement to show the presence of such special dome placards. This endorsement being in addition to the regular Inflammable Placard endorsement as required by the regulations.

Packages containing inflammable liquids must not be entirely filled. Sufficient interior space must be left vacant to prevent distortion by containers when heated to a temperature of 120 deg. fahr. (49 deg. cent.) This vacant space must not be less than 2 per cent of the capacity of the container including the dome capacity of tank cars.

1. The provisions of "Shipping-Container Specifications No. 5" apply to all containers specified therein that are purchased after December 31, 1911, and used for the shipment of dangerous articles other than explosives. Each such container purchased subsequently to December 31, 1911, shall have plainly stamped thereon the date of manufacture thereof.

2. An iron or steel barrel or drum with a capacity of from 50 to 55 gallons must have a minimum weight in the black, exclusive of the weight of rolling hoops, of 70 pounds, and the minimum thickness of metal in any part of the completed barrel must not be less than that of No. 16 gauge United States standard.

3. An iron or steel barrel or drum with a capacity of from 100 to 110 gallons must have a minimum weight in the black, exclusive of the rolling hoops, of not less than 130 pounds, and the minimum thickness of metal in any part of the completed barrel or drum must not be less than that of full No. 14 gauge United States standard.

4. Each barrel or drum must stand a manufacturers' test under water by interior compressed air at a pressure of not less than 15 pounds per square inch sustained for not less than two minutes, without leaking, and the type of barrel or drum must be capable of standing a hydrostatic test pressure of not less than 40 pounds per square inch, sustained for not less than five minutes, without any serious permanent deformation and without leaking.

5. When filled with water to 98 per cent of its capacity, the type of barrel or drum must also be capable of standing, without leakage, a test drop on its chime for a height of four feet upon a solid concrete foundation.

6. Bungs and other openings must be provided with secure closing devices that will not permit leakage through them. Threaded metal plugs must be close fitting. Gaskets must be made of lead, leather, or other suitable material. Wooden plugs must be covered with a suitable coating and must have a driving fit into a tapered hole.

7. The method of manufacturing the barrel or drum and the materials used must be well adapted to producing a uniform product. Leaks in a new barrel or drum must not be stopped by soldering, but must be repaired by the method used in constructing the barrel or drum.

Method of Making Vapor Pressure Tests and Remarks on Shipping Liquefied Petroleum Gas—(See Paragraph 1824, I. C. C. Regulations)—Remove the gauge from the tube and fill tube 90 per cent of its capacity. Fill tube preferably by lowering it into the storage tank in upright position by means of a cord or wire. Leave the tube entirely immersed for several minutes, withdraw it and pour off sufficient liquid so that it will contain 90 per cent of its capacity. A small measure having capacity of 10 per cent of the test tube should be used for that purpose.

In case it is impracticable to lower the tube into the storage tank, draw the liquid off into a vessel of a capacity about equal to the test tube. Pour liquid into the test tube until about half filled. Shake the tube and contents gently in order to bring both to the same temperature. After standing for several minutes, pour out all the liquid from the tube. Draw another sample from the storage tank into the cylinder and pour through funnel into the tube until the latter is entirely full. Withdraw one tenth as before. Screw gauge tightly into position using a little liquid shellac on the joint to insure a tight fit.

Immerse the tube in water at temperature of 70 deg. fahr. and allow it to remain for five minutes. Then remove it from the water and unscrew the gauge sufficiently to momentarily relieve the pressure indicated by the gauge, and immediately screw the gauge tightly into the tube again. Then place the tube in water at a temperature of 100 deg. fahr. (90 deg. fahr. from Nov. 1st to March 1st). The level of the water must be just below the lower edge of the pressure gauge. Stir the water continually and maintain the temperature exactly constant for ten minutes, then tap the gauge lightly with the finger and read the pressure.

A second test should be made on another sample of the gasoline proceeding as above except that, after closing the tube the first time, it is placed directly in water at 100 deg.

fahr., and the pressure read after 10 minutes. This second test is only for information and record.

Although the regular inspectors of the Bureau of Explosives are available for making these tests when required, still, the responsibility for knowing the vapor pressure of the liquid shipped and that it is in proper containers, rests entirely on the shippers, who should provide facilities and require frequent tests to be made of their product, and should send a copy of the results of such tests to the Chief Inspector, Bureau of Explosives, 30 Vesey Street, New York City, for information and record.

In making reports, the gravity of the liquid, the temperature of the liquid as placed in test tube, the pressure at 70 deg. fahr. before venting tube, the pressure at 100 deg. fahr. (90 deg. from Nov. 1st to March 1st) after venting at 70 deg. fahr. and the pressure at 100 deg. fahr. on tube not vented at 70 deg. fahr. should all be recorded.

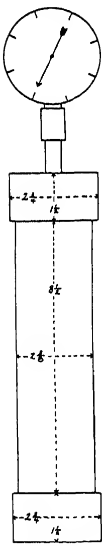

Fig. 54

Apparatus for Testing Vapor Pressure of Gasoline—Description of Apparatus—Apparatus shown in figure 54 consists of iron or steel pipe of two inch size with caps screwed on ends. Upper cap has 0.25 inch nipple screwed in and is connected by a coupling to a 3 inch 30 lb. pressure gauge. Gauge is known as Inspectors' Gas Gauge. All joints must be entirely tight. Joints between large pipe and caps are best sealed with solder. Approximate external dimensions are indicated on sketch. In addition to apparatus indicated in test, there is also required a tin cylinder for filling test tube 12 by 3 inches that can be slipped over outside of tube for convenience in carrying when not in use. The tin cylinder is provided with a lip for pouring. A small tin cover 0.75 inch deep, fitting over the bottom

of the tin cylinder may be removed and used for measuring off one tenth capacity of test tube. A small tin funnel 2.5 inches in diameter with stem 3 inches long and three sixteenths inch in diameter should be used.

Market—The main market for gasoline is for internal combustion engines such as automobiles, traction, motor boat, factory and the small farm engines. While no doubt the automobile is the greatest consumer, even the little farm engine is fast becoming a factor in its use of gasoline.

In 1905 automobiles consumed close to 30,000,000 gallons, while in 1916 it is estimated that the consumption of gasoline will amount to approximately 1,500,000,000 gallons or fifty times that of 1905.

While the automobile shows the greatest increase, all other types of internal combustion engines for various purposes have shown a most wonderful growth in numbers and have greatly increased the demand for gasoline.

In 1908, 86,000 automobiles were marketed and in 1916 it is conservatively predicted that the sale will reach 1,200,000.

On January 1, 1916 there were 2,225,000 automobiles in use and it is estimated there will be 3,200,000 in use by Jan. 1, 1917.

When it is taken into consideration that one automobile consumes 500 gallons of gasoline in a year, we can gain a faint idea of the fast increasing demand for gasoline even with a big allowance for old cars being abandoned.

The estimated increase of automobiles this year (1916) will alone cause an increased demand for gasoline of 9,000,000 barrels over the amount used in 1915.

PART NINE

Miscellaneous

Baume Scale and Specific Gravity Equivalent—The instruments used are a hydrometer and a standard thermometer. The hydrometer, which is a glass column marked with graduations from 10 to 100, was invented by Antoine Baume, a French chemist, and the scale on the instrument has always borne his name. The hydrometer, when placed in a jar or a bottle of oil, sinks to the point on the scale which indicates the gravity in degrees Baume. There are two Baume hydrometers—one which is used with liquids heavier than water with which the hydrometer sinks to 0 degrees in pure water and to 15 degrees in a 15 per cent salt solution; the other for liquids lighter than water which sinks to 0 degrees in a 10 per cent salt solution and to 10 degrees in pure water. With both hydrometers the graduations are based on the densities between the fundamental points and is continued along the stem of the hydrometer as far as desired.

The basis of temperature for testing oil is 60 deg. fahr., and for oil at a greater or less temperature, variations must be calculated. Hydrometers are usually provided with a special scale for figuring temperature variations.

All degrees on a Baume scale are thus equal in length while those on a specific gravity scale grow smaller as the density increases. There is no simple relation between degrees Baume and specific gravity; however, readings on the Baume scale may be approximately reduced to specific gravity by the following formulae:

For liquid heavier than water:

Specific gravity = 144 : (144 − x) in which x equals th

reading on the Baume scale.

For liquid lighter than water:

Specific gravity = 144 : (134 + x) in which x equals t

reading on the Baume scale.

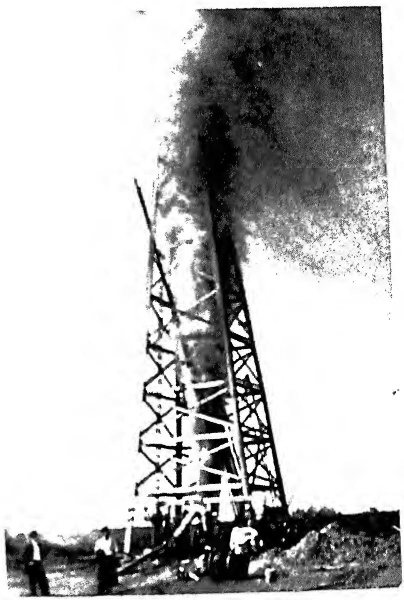

Fig. [illegible]

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER *

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
1.0000	10.	8.331	.9785	13.071	8.152
.9995	10.071	8.327	.9780	.142	8.148
.9990	.142	8.323	.9775	.214	8.144
.9985	.214	8.319	.9770	.286	8.139
.9980	.286	8.314	.9765	.357	8.135
.9975	.357	8.310	.9760	.428	8.131
.9970	.428	8.306	.9755	.500	8.127
.9965	.500	8.302	.9750	.571	8.123
.9960	.571	8.298	.9745	.642	8.119
.9955	.642	8.294	.9740	.714	8.114
.9950	.714	8.289	.9735	.785	8.110
.9945	.785	8.825	.9730	.857	8.106
.9940	.857	8.281	.9725	13.928	8.102
.9935	10.928	8.277	.9720	14.	8.098
.9930	11.	8.273	.9715	14.077	8.094
.9925	11.071	8.269	.9710	.154	8.089
.9920	.142	8.264	.9705	.231	8.085
.9915	.214	8.260	.9700	.308	8.081
.9910	.286	8.256	.9695	.462	8.077
.9905	.357	8.252	.9690	.538	8.073
.9900	.428	8.248	.9685	.615	8.069
.9895	.500	8.244	.9680	.692	8.064
.9890	.571	8.239	.9675	.769	8.060
.9885	.642	8.235	.9670	.846	8.056
.9880	.714	8.231	.9665	14.923	8.052
.9875	.785	8.227	.9660	15.	8.048
.9870	.857	8.223	.9655	15.077	8.044
.9865	11.928	8.219	.9650	.165	8.039
.9860	12.	8.214	.9645	.249	8.035
.9855	12.071	8.210	.9640	.332	8.031
.9850	.142	8.206	.9635	.415	8.027
.9845	.214	8.202	.9630	.498	8.023
.9840	.286	8.198	.9625	.581	8.019
.9835	.357	8.194	.9620	.664	8.014
.9830	.428	8.189	.9615	.747	8.010
.9825	.500	8.185	.9610	.830	8.006
.9820	.571	8.181	.9605	.913	8.002
.9815	.642	8.177	.9600	15.993	7.998
.9810	.714	8.173	.9595	16.	7.994
.9805	.785	8.169	.9590	16.083	7.989
.9800	.857	8.164	.9585	.165	7.985
.9795	12.928	8.160	.9580	.249	7.981
.9790	13.	8.156	.9575	.415	7.977

* Courtesy of Phoenix Refining Co.

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
.9570	.415	7.973	.9355	.747	7.794
.9565	.498	7.969	.9350	.830	7.789
.9560	.581	7.964	.9345	19.913	7.785
.9555	.664	7.960	.9340	20.	7.781
.9550	.747	7.956	.9335	20.083	7.777
.9545	.830	7.952	.9330	.166	7.773
.9540	.913	7.948	.9325	.249	7.769
.9535	16.994	7.944	.9320	.332	7.764
.9530	17.	7.939	.9315	.415	7.760
.9525	17.077	7.935	.9310	.498	7.756
.9520	.154	7.931	.9305	.581	7.752
.9515	.231	7.927	.9300	.664	7.748
.9510	.308	7.923	.9295	.747	7.744
.9505	.385	7.919	.9290	.830	7.739
.9500	.462	7.914	.9285	20.913	7.735
.9495	.538	7.910	.9280	21.	7.731
.9490	.615	7.906	.9275	21.083	7.727
.9485	.692	7.902	.9270	.166	7.723
.9480	.769	7.898	.9265	.249	7.719
.9475	.846	7.894	.9260	.332	7.715
.9470	17.923	7.889	.9255	.415	7.710
.9465	18.	7.885	.9250	.498	7.706
.9460	18.077	7.881	.9245	.581	7.702
.9455	.154	7.877	.9240	.664	7.698
.9450	.231	7.873	.9235	.747	7.694
.9445	.308	7.869	.9230	.830	7.690
.9440	.385	7.864	.9225	21.913	7.685
.9435	.462	7.860	.9220	22.	7.681
.9430	.538	7.856	.9215	22.09	7.677
.9425	.615	7.852	.9210	.18	7.673
.9420	.692	7.848	.9205	.27	7.669
.9415	.769	7.844	.9200	.36	7.665
.9410	.846	7.839	.9195	.45	7.660
.9405	.923	7.835	.9190	.54	7.656
.9400	19.000	7.831	.9185	.63	7.652
.9395	19.083	7.827	.9180	.72	7.648
.9390	.166	7.823	.9175	.81	7.644
.9385	.249	7.819	.9170	22.90	7.640
.9380	.332	7.815	.9165	23.	7.635
.9375	.415	7.811	.9160	23.08	7.631
.9370	.498	7.806	.9155	.17	7.627
.9365	.581	7.802	.9150	.25	7.623
.9360	.664	7.798	.9145	.33	7.619

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
.9140	.42	7.615	.8925	27.08	7.435
.9135	.50	7.610	.8920	.17	7.431
.9130	.58	7.606	.8915	.25	7.427
.9125	.66	7.602	.8910	.33	7.423
.9120	.75	7.598	.8905	.42	7.419
.9115	.83	7.594	.8900	.50	7.415
.9110	23.91	7.590	.8895	.58	7.410
.9105	24.	7.585	.8890	.66	7.406
.9100	24.08	7.581	.8885	.75	7.402
.9095	.17	7.577	.8880	.83	7.398
.9090	.25	7.573	.8875	27.91	7.394
.9085	.33	7.569	.8870	28.	7.390
.9080	.42	7.565	.8865	28.09	7.385
.9075	.50	7.560	.8860	.18	7.381
.9070	.58	7.556	.8855	.27	7.377
.9065	.66	7.552	.8850	.36	7.373
.9060	.75	7.548	.8845	.45	7.369
.9055	.83	7.544	.8840	.54	7.365
.9050	24.91	7.540	.8835	.63	7.360
.9045	25.	7.536	.8830	.72	7.356
.9040	25.09	7.531	.8825	.81	7.352
.9035	.18	7.527	.8820	28.90	7.348
.9030	.27	7.523	.8815	29.	7.344
.9025	.36	7.519	.8810	29.08	7.340
.9020	.45	7.515	.8805	.17	7.335
.9015	.54	7.510	.8800	.25	7.331
.9010	.63	7.506	.8795	.33	7.327
.9005	.72	7.502	.8790	.42	7.323
.9000	.81	7.498	.8785	.50	7.319
.8995	25.90	7.494	.8780	.58	7.315
.8990	26.	7.490	.8775	.66	7.310
.8985	26.08	7.485	.8770	.75	7.306
.8980	.17	7.481	.8765	.83	7.302
.8975	.25	7.477	.8760	29.91	7.298
.8970	.33	7.473	.8755	30.	7.294
.8965	.42	7.469	.8750	30.09	7.290
.8960	.50	7.465	.8745	.18	7.285
.8955	.58	7.460	.8740	.27	7.281
.8950	.66	7.456	.8735	.36	7.277
.8945	.75	7.452	.8730	.45	7.273
.8940	.83	7.448	.8725	.54	7.269
.8935	26.91	7.444	.8720	.63	7.265
.8930	27.	7.440	.8715	.72	7.260

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
.8710	.81	7.256	.8495	34.90	7.077
.8705	30.90	7.252	.8490	35.	7.073
.8700	31.	7.248	.8485	35.10	7.069
.8695	31.10	7.244	.8480	.20	7.065
.8690	.20	7.240	.8475	.30	7.061
.8685	.30	7.235	.8470	.40	7.056
.8680	.40	7.231	.8465	.50	7.052
.8675	.50	7.227	.8460	.60	7.048
.8670	.60	7.223	.8455	.70	7.044
.8665	.70	7.219	.8450	.80	7.040
.8660	.80	7.215	.8445	35.90	7.036
.8655	31.90	7.210	.8440	36.	7.031
.8650	32.	7.206	.8435	36.11	7.027
.8645	32.09	7.202	.8430	.22	7.023
.8640	.18	7.198	.8425	.33	7.019
.8635	.27	7.194	.8420	.44	7.015
.8630	.36	7.190	.8415	.55	7.011
.8625	.45	7.185	.8410	.66	7.006
.8620	.54	7.181	.8405	.77	7.002
.8615	.63	7.177	.8400	36.88	6.998
.8610	.72	7.173	.8395	37.	6.994
.8605	.81	7.169	.8390	37.10	6.990
.8600	32.90	7.165	.8385	.20	6.986
.8595	33.	7.160	.8380	.30	6.981
.8590	33.10	7.156	.8375	.40	6.977
.8585	.20	7.152	.8370	.50	6.973
.8580	.30	7.148	.8365	.60	6.969
.8575	.40	7.144	.8360	.70	6.965
.8570	.50	7.140	.8355	.80	6.961
.8565	.60	7.136	.8350	37.90	6.956
.8560	.70	7.131	.8345	38.	6.952
.8555	.80	7.127	.8340	38.10	6.948
.8550	33.90	7.123	.8335	.20	6.944
.8545	34.	7.119	.8330	.30	6.940
.8540	34.09	7.115	.8325	.40	6.936
.8535	.18	7.111	.8320	.50	6.931
.8530	.27	7.106	.8315	.60	6.927
.8525	.36	7.102	.8310	.70	6.923
.8520	.45	7.098	.8305	.80	6.919
.8515	.54	7.094	.8300	38.90	6.915

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER

Gravity Specific	Gravity Baume	Pounds per Gallon	Gravity Specific	Gravity Baume	Pounds per Gallon
.8280	.33	6.898	.8065	44.	6.719
.8275	.44	6.894	.8060	44.10	6.715
.8270	.55	6.890	.8055	.20	6.711
.8265	.66	6.886	.8050	.30	6.706
.8260	.77	6.881	.8045	.40	6.702
.8255	39.88	6.877	.8040	.50	6.698
.8250	40.	6.873	.8035	.60	6.694
.8245	40.11	6.869	.8030	.70	6.690
.8240	.22	6.865	.8025	.80	6.686
.8235	.33	6.861	.8020	44.90	6.681
.8230	.44	6.856	.8015	45.	6.677
.8225	.55	6.852	.8010	45.11	6.673
.8220	.66	6.848	.8005	.22	6.669
.8215	.77	6.844	.8000	.33	6.665
.8210	40.88	6.840	.7995	.44	6.661
.8205	41.	6.836	.7990	.55	6.656
.8200	41.10	6.831	.7985	.66	6.652
.8195	.20	6.827	.7980	.77	6.648
.8190	.30	6.823	.7975	45.88	6.644
.8185	.40	6.819	.7970	46.	6.640
.8180	.50	6.815	.7965	46.11	6.636
.8175	.60	6.811	.7960	.22	6.631
.8170	.70	6.806	.7955	.33	6.627
.8165	.80	6.802	.7950	.44	6.623
.8160	41.90	6.798	.7945	.55	6.619
.8155	42.	6.794	.7940	.66	6.615
.8150	42.11	6.790	.7935	.77	6.611
.8145	.22	6.786	.7930	46.88	6.606
.8140	.33	6.781	.7925	47.	6.602
.8135	.44	6.777	.7920	47.12	6.598
.8130	.55	6.773	.7915	.24	6.594
.8125	.66	6.769	.7910	.36	6.590
.8120	.77	6.765	.7905	.48	6.586
.8115	42.88	6.761	.7900	.60	6.581
.8110	43.	6.756	.7895	.72	6.577
.8105	43.11	6.752	.7890	47.84	6.573
.8100	.22	6.748	.7885	48.	6.569
.8095	.33	6.744	.7880	48.11	6.565
.8090	.44	6.740	.7875	.22	6.561
.8085	.55	6.736	.7870	.33	6.556
.8080	.66	6.731	.7865	.44	6.552
.8075	.77	6.727	.7860	.55	6.548
.8070	43.88	6.723	.7855	.66	6.544

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
.7850	.77	6.540	.7635	53.85	6.361
.7845	48.88	6.536	.7630	54.	6.357
.7840	49.	6.532	.7625	54.11	6.352
.7835	49.11	6.527	.7620	.22	6.348
.7830	.22	6.523	.7615	.33	6.344
.7825	.33	6.519	.7610	.44	6.340
.7820	.44	6.515	.7605	.55	6.336
.7815	.55	6.511	.7600	.66	6.332
.7810	.66	6.507	.7595	.77	6.327
.7805	.77	6.502	.7590	54.88	6.323
.7800	49.88	6.498	.7585	55.	6.319
.7795	50.	6.494	.7580	55.12	6.315
.7790	50.11	6.490	.7575	.24	6.311
.7785	.22	6.486	.7570	.36	6.307
.7780	.33	6.482	.7565	.48	6.302
.7775	.44	6.477	.7560	.60	6.298
.7770	.55	6.473	.7555	.72	6.294
.7765	.66	6.469	.7550	55.85	6.290
.7760	.77	6.465	.7545	56.	6.286
.7755	50.88	6.461	.7540	56.12	6.282
.7750	51.	6.457	.7535	.24	6.277
.7745	51.12	6.452	.7530	.36	6.273
.7740	.24	6.448	.7525	.48	6.269
.7735	.36	6.444	.7520	.60	6.265
.7730	.48	6.440	.7515	.72	6.261
.7725	.60	6.436	.7510	56.85	6.257
.7720	.72	6.432	.7505	57.	6.252
.7715	51.85	6.427	.7500	57.14	6.248
.7710	52.	6.423	.7495	.28	6.244
.7705	52.12	6.419	.7490	.42	6.240
.7700	.24	6.415	.7485	.56	6.236
.7695	.36	6.411	.7480	.70	6.232
.7690	.48	6.407	.7475	57.84	6.227
.7685	.60	6.402	.7470	58.	6.223
.7680	.72	6.398	.7465	58.12	6.219
.7675	52.85	6.394	.7460	.24	6.215
.7670	53.	6.390	.7455	.36	6.211
.7665	53.12	6.386	.7450	.48	6.207
.7660	.24	6.382	.7445	.60	6.202
.7655	.36	6.377	.7440	.72	6.198
.7650	.48	6.373	.7435	58.85	6.194
.7645	.60	6.369	.7430	59.	6.190
.7640	.72	6.365	.7425	59.12	6.186

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
.7420	.24	6.182	.7205	65.	6.002
.7415	.36	6.177	.7200	65.14	5.998
.7410	.48	6.173	.7195	.28	5.994
.7405	.60	6.169	.7190	.42	5.990
.7400	.72	6.165	.7185	.56	5.986
.7395	59.84	6.161	.7180	.70	5.982
.7390	60.	6.157	.7175	.84	5.977
.7385	60.14	6.153	.7170	65.95	5.973
.7380	.28	6.148	.7165	66.	5.969
.7375	.42	6.144	.7160	66.14	5.965
.7370	.56	6.140	.7155	.28	5.961
.7365	.70	6.136	.7150	.42	5.957
.7360	60.84	6.132	.7145	.56	5.952
.7355	61.	6.127	.7140	.70	5.948
.7350	61.12	6.123	.7135	66.85	5.944
.7345	.24	6.119	.7130	67.	5.940
.7340	.36	6.115	.7125	67.14	5.936
.7335	.48	6.111	.7120	.28	5.932
.7330	.60	6.107	.7115	.42	5.928
.7325	.72	6.102	.7110	.56	5.923
.7320	61.85	6.098	.7105	.70	5.919
.7315	62.	6.094	.7100	67.85	5.915
.7310	62.14	6.090	.7095	68.	5.911
.7305	.28	6.086	.7090	68.14	5.907
.7300	.42	6.082	.7085	.28	5.903
.7295	.56	6.077	.7080	.42	5.898
.7290	.70	6.073	.7075	.56	5.894
.7285	62.85	6.069	.7070	.70	5.890
.7280	63.	6.065	.7065	68.85	5.886
.7275	63.12	6.061	.7060	69.	5.882
.7270	.24	6.057	.7055	69.14	5.878
.7265	.36	6.052	.7050	.28	5.873
.7260	.48	6.048	.7045	.42	5.869
.7255	.60	6.044	.7040	.56	5.865
.7250	.72	6.040	.7035	.70	5.861
.7245	63.85	6.036	.7030	69.85	5.857
.7240	64.	6.032	.7025	70.	5.853
.7235	64.14	6.027	.7020	70.14	5.848
.7230	.28	6.023	.7015	.28	5.844
.7225	.42	6.019	.7010	.42	5.840
.7220	.56	6.015	.7005	.56	5.836
.7215	.70	6.011	.7000	.70	5.832
.7210	64.85	6.007	.6995	70.84	5.828

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
.6990	71.	5.823	.6775	.42	5.644
.6985	71.14	5.819	.6770	.56	5.640
.6980	.28	5.815	.6765	.70	5.636
.6975	.42	5.811	.6760	77.85	5.632
.6970	.56	5.807	.6755	78.	5.628
.6965	.70	5.803	.6750	78.14	5.623
.6960	71.85	5.798	.6745	.28	5.619
.6955	72.	5.794	.6740	.42	5.615
.6950	72.14	5.790	.6735	.56	5.611
.6945	.28	5.786	.6730	.70	5.607
.6940	.42	5.782	.6725	78.85	5.603
.6935	.56	5.778	.6720	79.	5.598
.6930	.70	5.773	.6715	79.16	5.594
.6925	72.85	5.769	.6710	.32	5.590
.6920	73.	5.765	.6705	.48	5.586
.6915	73.16	5.761	.6700	.65	5.582
.6910	.32	5.757	.6695	79.82	5.578
.6905	.48	5.753	.6690	80.	5.573
.6900	.65	5.748	.6685	80.14	5.569
.6895	73.82	5.744	.6680	.28	5.565
.6890	74.	5.740	.6675	.42	5.561
.6885	74.14	5.736	.6670	.56	5.557
.6880	.28	5.732	.6665	.70	5.553
.6875	.42	5.728	.6660	80.85	5.548
.6870	.56	5.723	.6655	81.	5.544
.6865	.70	5.719	.6650	81.14	5.540
.6860	74.85	5.715	.6645	.28	5.536
.6855	75.	5.711	.6640	.42	5.532
.6850	75.14	5.707	.6635	.56	5.528
.6845	.28	5.703	.6630	.70	5.523
.6840	.42	5.698	.6625	81.85	5.519
.6835	.56	5.694	.6620	82.	5.515
.6830	.70	5.690	.6615	82.14	5.511
.6825	75.85	5.686	.6610	.28	5.507
.6820	76.	5.682	.6605	.42	5.503
.6815	76.16	5.678	.6600	.56	5.498
.6810	.32	5.673	.6595	.70	5.494
.6805	.48	5.669	.6590	82.85	5.490
.6800	.65	5.655	.6585	83.	5.486
.6795	76.82	5.661	.6580	83.12	5.482
.6790	77.	5.657	.6575	.24	5.478
.6785	77.14	5.653	.6570	.36	5.473
.6780	.28	5.648	.6565	.48	5.469

GRAVITIES AND WEIGHTS OF LIQUIDS LIGHTER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
.6560	.60	5.465	.6460	.65	5.382
.6555	.72	5.461	.6455	86.82	5.378
.6550	83.85	5.457	.6450	87.	5.373
.6545	84.	5.453	.6445	87.16	5.369
.6540	84.14	5.448	.6440	.32	5.365
.6535	.28	5.444	.6435	.48	5.361
.6530	.42	5.440	.6430	.65	5.357
.6525	.56	5.436	.6425	87.82	5.353
.6520	.70	5.432	.6420	88.	5.349
.6515	84.85	5.428	.6415	88.16	5.344
.6510	85.	5.423	.6410	.32	5.340
.6505	85.16	5.419	.6405	.48	5.336
.6500	.32	5.415	.6400	.65	5.332
.6495	.48	5.411	.6395	88.82	5.328
.6490	.65	5.407	.6390	89.	5.324
.6485	85.82	5.403	.6385	89.20	5.319
.6480	86.	5.398	.6380	.40	5.315
.6475	86.16	5.394	.6375	.60	5.311
.6470	.32	5.390	.6370	89.80	5.307
.6465	.48	5.386	.6365	90.	5.303

GRAVITIES AND WEIGHTS OF LIQUIDS HEAVIER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
1.0000	0.	8.331	1.1328	17.	9.436
1.0050	0.72	8.373	1.1350	17.25	9.457
1.0069	1.	8.388	1.1400	17.81	9.497
1.0100	1.44	8.414	1.1417	18.	9.512
1.0140	2.	8.448	1.1450	18.36	9.539
1.0150	2.14	8.456	1.1500	18.91	9.581
1.0200	2.84	8.498	1.1508	19.	9.587
1.0211	3.	8.507	1.1550	19.46	9.611
1.0250	3.54	8.539	1.1600	20.	9.664
1.0284	4.	8.568	1.1650	20.54	9.706
1.0300	4.22	8.581	1.1694	21.	9.744
1.0350	4.90	8.623	1.1700	21.07	9.747
1.0357	5.	8.628	1.1750	21.60	9.789
1.0400	5.58	8.664	1.1789	22.	9.821
1.0432	6.	8.691	1.1800	22.12	9.831
1.0450	6.24	8.706	1.1850	22.64	9.872
1.0500	6.90	8.748	1.1885	23.	9.901
1.0507	7.	8.753	1.1900	23.15	9.913
1.0550	7.56	8.789	1.1950	23.66	9.956
1.0584	8.	8.818	1.1983	24.	9.930
1.0600	8.21	8.841	1.2000	24.17	9.997
1.0650	8.25	8.873	1.2050	24.67	10.039
1.0662	9.	8.883	1.2083	25.	10.066
1.0700	9.49	8.914	1.2100	25.17	10.080
1.0741	10.	8.948	1.2150	25.66	10.122
1.0750	10.12	8.956	1.2185	26.	10.141
1.0800	10.74	8.997	1.2200	26.15	10.164
1.0821	11.	9.015	1.2250	26.63	10.205
1.0850	11.36	9.039	1.2288	27.	10.237
1.0900	11.97	9.081	1.2300	27.11	10.247
1.0902	12.	9.082	1.2350	27.59	10.289
1.0950	12.58	9.122	1.2393	28.	10.325
1.0985	13.	9.151	1.2400	28.06	10.330
1.1000	13.18	9.164	1.2450	28.53	10.372
1.1050	13.78	9.206	1.2500	29.	10.414
1.1069	14.	9.221	1.2550	29.46	10.455
1.1100	14.37	9.247	1.2600	29.92	10.497
1.1150	14.96	9.289	1.2609	30.	10.505
1.1154	15.	9.292	1.2650	30.38	10.539
1.1200	15.54	9.331	1.2700	30.83	10.580
1.1240	16.	9.364	1.2719	31.	10.596
1.1250	16.11	9.372	1.2750	31.27	10.622
1.1300	16.68	9.414	1.2800	31.72	10.664

GRAVITIES AND WEIGHTS OF LIQUIDS HEAVIER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
1.2832	32.	10.690	1.4400	44.30	11.997
1.2850	32.16	10.712	1.4450	44.65	12.038
1.2900	32.60	10.745	1.4500	45.	12.080
1.2946	33.	10.785	1.4550	45.24	12.122
1.2950	33.03	10.789	1.4600	45.68	12.163
1.3000	33.46	10.830	1.4646	46.	12.202
1.3050	33.89	10.872	1.4650	46.02	12.205
1.3063	34.	10.883	1.4700	46.36	12.247
1.3100	34.31	10.914	1.4750	46.69	12.289
1.3150	34.73	10.955	1.4796	47.	12.327
1.3182	35.	10.982	1.4800	47.03	12.330
1.3200	35.15	10.997	1.4850	47.36	12.373
1.3250	35.57	11.039	1.4900	47.68	12.413
1.3300	35.98	11.071	1.4948	48.	12.453
1.3303	36.	11.083	1.4950	48.01	12.455
1.3350	36.38	11.121	1.5000	48.33	12.497
1.3400	36.79	11.164	1.5050	48.65	12.538
1.3426	37.	11.185	1.5100	48.97	12.580
1.3450	37.19	11.205	1.5104	49.	12.583
1.3500	37.59	11.247	1.5150	49.29	12.621
1.3551	38.	11.289	1.5200	49.61	12.663
1.3600	38.38	11.330	1.5250	49.92	12.705
1.3650	38.77	11.371	1.5263	50.	12.716
1.3679	39.	11.396	1.5300	50.23	12.746
1.3700	39.16	11.413	1.5350	50.54	12.788
1.3750	39.55	11.455	1.5400	50.84	12.830
1.3800	39.93	11.497	1.5426	51.	12.851
1.3810	40.	11.505	1.5450	51.15	12.871
1.3850	40.39	11.538	1.5500	51.45	12.913
1.3900	40.68	11.580	1.5550	51.75	12.955
1.3942	41.	11.621	1.5591	52.	12.999
1.3950	41.06	11.622	1.5600	52.05	12.996
1.4000	41.43	11.663	1.5650	52.35	13.038
1.4050	41.80	11.705	1.5700	52.64	13.080
1.4078	42.	11.728	1.5750	52.94	13.121
1.4100	42.16	11.747	1.5761	53.	13.130
1.4150	42.53	11.788	1.5800	53.23	13.163
1.4200	42.89	11.830	1.5850	53.52	13.205
1.4216	43.	11.843	1.5900	53.81	13.246
1.4250	43.24	11.872	1.5934	54.	13.275
1.4300	43.60	11.913	1.5950	54.09	13.288
1.4350	43.95	11.955	1.6000	54.38	13.330
1.4356	44.	11.960	1.6050	54.66	13.371

GRAVITIES AND WEIGHTS OF LIQUIDS HEAVIER THAN WATER

Gravity		Pounds per Gallon	Gravity		Pounds per Gallon
Specific	Baume		Specific	Baume	
1.6100	54.94	13.413	1.7700	63.08	14.746
1.6111	55.	13.422	1.7750	63.31	14.788
1.6150	55.22	13.456	1.7800	63.54	14.829
1.6200	55.49	13.496	1.7850	63.77	14.871
1.6250	55.77	13.538	1.7901	64.	14.908
1.6292	56.	13.573	1.7950	64.22	14.954
1.6300	56.04	13.580	1.8000	64.45	14.996
1.6350	56.31	13.621	1.8050	64.67	15.037
1.6400	56.59	13.663	1.8100	64.89	15.079
1.6450	56.85	13.704	1.8125	65.	15.100
1.6477	57.	13.726	1.8150	65.11	15.121
1.6500	57.12	13.746	1.8200	65.33	15.162
1.6550	57.38	13.788	1.8250	65.55	15.204
1.6600	57.65	13.829	1.8300	65.77	15.246
1.6650	57.91	13.871	1.8350	65.98	15.287
1.6667	58.	13.885	1.8354	66.	15.291
1.6700	58.17	13.913	1.8400	66.20	15.329
1.6750	58.43	13.954	1.8450	66.41	15.371
1.6800	58.69	13.996	1.8500	66.62	15.412
1.6850	58.95	14.038	1.8550	66.83	15.454
1.6860	59.	14.046	1.8589	67.	15.486
1.6900	59.20	14.079	1.8600	67.04	15.496
1.6950	59.45	14.121	1.8650	67.25	15.537
1.7000	59.71	14.163	1.8700	67.46	15.579
1.7050	59.96	14.204	1.8750	67.67	15.621
1.7059	60.	14.212	1.8800	67.87	15.662
1.7100	60.20	14.246	1.8831	68.	15.688
1.7150	60.45	14.288	1.8850	68.08	15.704
1.7200	60.70	14.329	1.8900	68.28	15.746
1.7250	60.94	14.371	1.8950	68.48	15.787
1.7262	61.	14.381	1.9000	68.68	15.829
1.7300	61.18	14.413	1.9050	68.88	15.871
1.7350	61.43	14.454	1.9079	69.	15.885
1.7400	61.67	14.496	1.9100	69.08	15.912
1.7450	61.91	14.538	1.9150	69.28	15.954
1.7470	62.	14.554	1.9200	69.48	15.996
1.7500	62.14	14.569	1.9250	69.68	16.037
1.7550	62.38	14.621	1.9300	69.87	16.079
1.7600	62.61	14.663	1.9333	70.	16.106
1.7650	62.85	14.704			
1.7683	63.	14.714			

Centigrade and Fahrenheit Scales — Thermometry is the art of measuring temperatures. The term "thermometer" is derived from the Greek words "therme" (heat) and "metron" (measure), meaning, therefore, "heat measure." This interpretation, however, should not be employed literally, for thermometers do not measure heat but, rather, the degree or intensity of heat.

In 1714 Gabriel Daniel Fahrenheit (1676-1736) conceived the idea of using mercury (quicksilver) as the indicating liquid in thermometers. He constructed such a thermometer and proceeded to graduate it, calling "body temperature" 24, and the freezing and boiling points of water 8 and 53 respectively. Fahrenheit considered the unit of temperature too large. Retaining his original zero as the datum point he divided each division of the scale into 4; accordingly the freezing point of water became 32 degrees and the boiling point 212 degrees.

The Centigrade or Celsius thermometric scale was originated by Anders Celsius (1701-1744) in 1741. He called the point to which the mercury fell when immersed in melting ice, zero, and the boiling point of water 100, and divided the interval between these points into 100 equal divisions. The Centigrade scale is universally used by scientists.

Comparing the Fahrenheit and Centigrade scales we note that 180 fahr. degrees equals 100 cent. degrees, or 1 cent. degree equals nine-fifths degrees. This relation exists over the entire scale. To convert Centigrade into Fahrenheit degrees, however, we cannot simply multiply the former by nine fifths, for we note that the zero or starting points of the scales are not coincident; consequently, a correction of 32 (the difference between the two scales at the melting point of ice) must be made.

The following formulae are used to convert one temperature reading into the other and are the bases of the table on page 234.

Cent. degrees = (fahr. degrees — 32) $\times$ 5/9
Fahr. degrees = (cent. degrees $\times$ 9/5) + 32

TABLE FOR CONVERTING CENTIGRADE TO FAHRENHEIT

deg. cent.	0	1	2	3	4	5	6	7	8	9
—40	—40	—42	—44	—45	—47	—49	—51	—53	—54	—56
—30	—22	—24	—26	—27	—29	—31	—33	—35	—36	—38
—20	— 4	— 6	— 8	— 9	—11	—13	—15	—17	—18	—20
—10	14	12	10	9	7	5	3	— 1	0	— 2
— 0	32	30	28	27	25	23	21	19	18	16
0	32	34	36	37	39	41	43	45	46	48
10	50	52	54	56	57	59	61	63	64	66
20	68	70	72	73	75	77	78	81	82	84
30	86	88	90	91	93	95	97	99	100	102
40	104	106	108	109	111	113	115	117	118	120
50	122	124	126	127	129	131	133	135	136	138
60	140	142	143	145	147	149	151	153	154	156
70	158	160	162	163	165	167	169	171	172	174
80	176	178	180	181	183	185	187	189	190	192
90	194	196	198	199	201	203	205	207	208	210
100	212	214	216	217	219	221	223	225	226	228
110	230	232	234	235	237	239	241	243	244	246
120	248	250	252	253	255	257	259	261	262	264
130	266	268	270	271	273	275	277	279	280	282
140	284	286	288	289	291	293	295	297	298	300
150	302	304	306	307	309	311	313	315	316	318
160	320	322	324	325	327	329	331	333	334	336
170	338	340	342	343	345	347	349	351	352	354
180	356	358	360	361	363	365	367	369	370	372
190	374	376	378	379	381	383	385	387	388	390
200	392	394	396	397	399	401	403	405	406	408
210	410	412	414	415	417	419	421	423	424	426
220	428	430	432	433	435	437	439	441	442	444

deg. cent.	0	1	2	3	4	5	6	7	8	9
230	446	448	450	451	453	455	457	459	460	462
240	464	466	468	469	471	473	475	477	478	480
250	482	484	486	487	489	491	493	495	496	498
260	500	502	504	505	507	509	511	513	514	516
270	518	520	522	523	525	527	529	531	532	534
280	536	538	540	541	543	545	547	549	550	552
290	554	556	558	559	561	563	565	567	568	570
300	572	574	576	577	579	581	583	585	586	588
310	590	592	594	595	597	599	601	603	604	606
320	608	610	612	613	615	617	619	621	622	624
330	626	628	630	631	633	635	637	639	640	642
340	644	646	648	649	651	653	655	657	658	660
350	662	664	666	667	669	671	673	675	676	678
360	680	682	684	685	687	689	691	693	694	696
370	698	700	702	703	705	707	709	711	712	714
380	716	718	720	721	723	725	727	729	730	732
390	734	736	738	739	741	743	745	747	748	750
400	752	754	756	757	759	761	763	765	766	768
410	770	772	774	775	777	779	781	783	784	786
420	788	790	792	793	795	797	799	801	802	804
430	806	808	810	811	813	815	817	819	820	822
440	824	826	828	829	831	833	835	837	838	840
450	842	844	846	847	849	851	853	855	856	858
460	860	862	864	865	867	869	871	873	874	876
470	878	880	882	883	885	887	889	891	892	894
480	896	898	900	901	903	905	907	909	910	912
490	914	916	918	919	921	923	925	927	928	930
500	932	934	936	937	939	941	944	945	946	948

TANK MEASUREMENTS *

THESE TABLES ARE INTENDED TO ASSIST IN COMPUTING CAPACITIES OF CIRCULAR TANKS, VERTICAL AND HORIZONTAL.

THE FOLLOWING FORMULAS ARE TO BE USED FOR COMPUTING CAPACITIES OF TANKS OF BOTH TYPES.

D = Diameter.
C = Circumference.
U. S. gal. = United States gal. of 231 cubic inches.
IMP. gal. = Imperial gal. of 277.274 cubic inches.
D in inches squared $\times$ 0.0034 = U. S. gal. per inch.
D in inches squared $\times$ 0.00283257 = Imp. gal. per inch.
D in feet squared $\times$ 0.011656 = 42 U. S. gal. bbls. per inch.
C in feet squared $\div$ 20.1586 = U. S. gal. per inch.
C in feet squared $\times$ 0.04960677 = U. S. gal. per inch.
C in feet squared $\times$ 0.00118111 = 42 U. S. gal. bbls. per inch.
C in feet squared $\times$ 0.00099213 = 50 U. S. gal. bbls. per inch.
C in feet squared $\times$ 0.041327896 = Imp. gal. per inch.
Imp. gal. $\div$ 1.20032 = U. S. gal.
U. S. gal. $\times$ 0.83311 = Imp. gal.
C of Circle = D $\times$ 3.14159.
D of Circle = C $\times$ 0.3183.
Area of Circle = $D^2 \times 0.7854$, also $C^2 \times 0.07958$.
D of true sphere in inches cubed $\times$ 0.0022666 = U. S. gal. in sphere.
U. S. gal. at any inch in true sphere (= 3D—2N) $N^2 \times 0.0022666$, in which N = height in inches, the diameter being also in inches.

Where N is more than ½ D, compute capacity of sphere and deduct capacity of empty section, in which case the N in the above formula becomes inches of space.

To find internal circumference of tank, deduct from external circumference in feet 0.033 of a foot for each one sixteenth of an inch thickness of iron and use internal circumference in making table.

*Courtsey of the Phoenix Refining Co.

THE MANNER OF USING TABLES FOR VERTICAL TANKS WILL BE READILY UNDERSTOOD FROM THE FOLLOWING EXAMPLES.

What is the capacity per inch of a tank 92 inches ln diameter? Opposite 92 in column "Diameter in Inches" read 28.778 United States gal.; 23.975 Imperial gal.; 0.685 bbls. of 42 gal., etc.

What is capacity per inch of a tank 92.5 inches in diameter?
Opposite 92, as above, read........................28.778 U. S. gal.
Difference between 92 and 93 is 0.629. One-half... 0.3145 U. S. gal.
92.5 =29.0925

The tables for each foot in circumference are used in the same manner.

Example: What is the capacity per inch of a tank 210.40 feet in internal circumference?
Opposite 210 in column "Circumference in feet"
read.......................................2187.658 U. S. gal.
Difference between 210 and 211 is 20.885, which
multiplied by 0.40 gives...................... 8.354 U. S. gal.
to be added, making........................2196.012 U. S. gal.
Capacity at 210.40 Feet.

The following example illustrates the method of measurement of horizontal tanks:
Diameter =50 inches.
To find U. S. gal. in segment A C E.
Height of segment 11 inches.

$\frac{14}{25}$ =Cosine angle A B D.

$\frac{2 \text{ Angle A B D}}{360}$ × area of circle area sector A B C E.

14 × 25 × sine angle A B D =area triangle A B C.

Area sector A B C E—srea triangle A B C =area segment A C E in inches.

$\frac{\text{Area segment A C E in inches}}{231}$ × Length of tank in inches =U. S. gal. when tank has 11 inches in.

The method of use of tables for horizontal tanks is to be found immediately preceding the tables for horizontal tanks on page 245.

VERTICAL TANKS

Gallons per Inch		Diameter in Inches	Barrels per Inch	
Imperial	U. S.		42 U.S. gal.	50 U.S. gal.
3.671	4.406	36	.105	.088
3.878	4.655	37	.111	.093
4.090	4.910	38	.117	.098
4.308	5.171	39	.123	.103
4.532	5.440	40	.130	.109
4.762	5.715	41	.136	.114
4.997	5.998	42	.143	.120
5.237	6.287	43	.150	.126
5.484	6.582	44	.157	.132
5.736	6.885	45	.164	.138
5.994	7.194	46	.171	.144
6.257	7.511	47	.179	.150
6.526	7.834	48	.187	.157
6.801	8.163	49	.194	.163
7.081	8.500	50	.202	.170
7.368	8.843	51	.211	.177
7.659	9.194	52	.219	.184
7.957	9.551	53	.227	.191
8.259	9.914	54	.236	.198
8.569	10.285	55	.245	.206
8.883	10.662	56	.254	.213
9.203	11.047	57	.263	.221
9.529	11.438	58	.272	.229
9.860	11.835	59	.282	.237
10.197	12.240	60	.291	.245
10.540	12.651	61	.301	.253
10.888	13.070	62	.311	.261
11.242	13.495	63	.321	.270
11.602	13.926	64	.332	.279
11.968	14.365	65	.342	.287
12.339	14.810	66	.353	.296
12.715	15.263	67	.363	.305
13.098	15.722	68	.374	.314
13.486	16.187	69	.385	.324
13.880	16.660	70	.397	.333
14.279	17.139	71	.408	.343
14.684	17.626	72	.420	.353
15.094	18.119	73	.431	.362
15.511	18.618	74	.443	.372
15.933	19.125	75	.455	.383
16.361	19.638	76	.468	.393
16.794	20.159	77	.480	.403
17.233	20.686	78	.493	.414
17.678	21.219	79	.505	.424
18.128	21.760	80	.518	.435

VERTICAL TANKS

Gallons per Inch		Diameter in Inches	Barrels per Inch	
Imperial	U. S.		42 U.S. gal.	50 U.S. gal.
18.584	22.307	81	.531	.446
19.046	22.862	82	.544	.457
19.514	23.423	83	.558	.468
19.986	23.990	84	.571	.480
20.465	24.565	85	.585	.491
20.950	25.146	86	.599	.503
21.440	25.735	87	.613	.515
21.935	26.330	88	.627	.526
22.437	26.931	89	.641	.539
22.944	27.540	90	.656	.551
23.457	28.155	91	.670	.563
23.975	28.778	92	.685	.575
24.499	29.407	93	.700	.588
25.029	30.042	94	.715	.601
25.564	30.685	95	.731	.614
26.105	31.334	96	.746	.627
26.652	31.991	97	.762	.640
27.204	32.654	98	.777	.653
27.762	33.324	99	.793	.666
28.326	34.000	100	.810	.680
28.895	34.683	101	.826	.694
29.470	35.374	102	.842	.707
30.051	36.071	103	.859	.721
30.637	36.774	104	.876	.735
31.229	37.485	105	.892	.750
31.827	38.202	106	.910	.764
32.430	38.927	107	.927	.778
33.039	39.658	108	.944	.793
33.654	40.395	109	.962	.808
34.274	41.140	110	.980	.823
34.900	41.891	111	.997	.838
35.532	42.645	112	1.015	.853
36.169	43.415	113	1.034	.868
36.812	44.186	114	1.052	.884
37.461	44.965	115	1.071	.899
38.115	45.750	116	1.089	.915
38.775	46.543	117	1.108	.931
39.441	47.342	118	1.127	.947
40.112	48.147	119	1.146	.963
40.789	48.960	120	1.166	.979
41.472	49.779	121	1.185	.995
42.160	50.606	122	1.205	1.012
42.854	51.439	123	1.225	1.029
43.554	52.278	124	1.244	1.045
44.259	53.125	125	1.265	1.062

VERTICAL TANKS

Gallons per Inch		Diameter in Inches	Barrels per Inch	
Imperial	U. S.		42 U.S. gal.	50 U.S. gal.
44.970	53.978	126	1.285	1.079
45.687	54.839	127	1.306	1.097
46.409	55.706	128	1.326	1.114
47.137	56.579	129	1.347	1.131
47.870	57.460	130	1.368	1.149
48.610	58.347	131	1.389	1.167
49.355	59.242	132	1.411	1.185
50.105	60.143	133	1.432	1.203
50.862	61.050	134	1.454	1.221
51.624	61.965	135	1.475	1.239
52.391	62.886	136	1.497	1.258
53.165	63.815	137	1.520	1.276
53.943	64.750	138	1.542	1.295
54.728	65.691	139	1.564	1.314
55.518	66.640	140	1.587	1.333
56.314	67.595	141	1.609	1.352
57.116	68.558	142	1.632	1.371
57.923	69.527	143	1.656	1.390
58.736	70.502	144	1.679	1.410
59.555	71.485	145	1.702	1.430
60.379	72.474	146	1.726	1.449
61.209	73.471	147	1.749	1.469
62.045	74.474	148	1.773	1.489
62.886	75.483	149	1.797	1.510
63.733	76.500	150	1.822	1.530
64.585	77.523	151	1.846	1.550
65.444	78.554	152	1.870	1.571
66.308	79.591	153	1.895	1.592
67.177	80.634	154	1.920	1.613
68.052	81.685	155	1.945	1.634
68.933	82.742	156	1.970	1.655
69.820	83.807	157	1.995	1.676
70.712	84.878	158	2.021	1.697
71.610	85.955	159	2.047	1.719
72.514	87.040	160	2.072	1.741
73.423	88.131	161	2.098	1.763
74.338	89.230	162	2.124	1.784
75.259	90.335	163	2.151	1.807
76.185	91.446	164	2.177	1.829
77.117	92.565	165	2.204	1.851
78.054	93.690	166	2.231	1.874
78.998	94.823	167	2.258	1.896
79.946	95.962	168	2.285	1.919
80.901	97.107	169	2.312	1.942
81.861	98.260	170	2.340	1.965

VERTICAL TANKS

Gallons per Inch		Diameter in Inches	Barrels per Inch	
Imperial	U. S.		42 U.S. gal.	50 U.S. gal.
82.827	99.419	171	2.367	1.988
83.799	100.586	172	2.395	2.012
84.776	101.759	173	2.423	2.035
85.759	102.939	174	2.451	2.059
86.747	104.125	175	2.479	2.082
87.452	105.318	176	2.508	2.106
88.742	106.519	177	2.536	2.130
89.747	107.726	178	2.565	2.154
90.758	108.939	179	2.594	2.179
91.775	110.160	180	2.623	2.203
92.798	111.387	181	2.652	2.228
93.826	112.622	182	2.681	2.252
94.860	113.863	183	2.711	2.277
95.899	115.110	184	2.741	2.302
96.945	116.365	185	2.771	2.327
97.996	117.626	186	2.801	2.352
99.052	118.895	187	2.831	2.378
100.114	120.170	188	2.861	2.403
101.182	121.451	189	2.892	2.429
102.256	122.740	190	2.922	2.454
103.335	124.035	191	2.953	2.481
104.420	125.338	192	2.984	2.507
105.510	126.647	193	3.016	2.533
106.607	127.962	194	3.047	2.559
107.708	129.285	195	3.078	2.586
108.816	130.614	196	3.110	2.612
109.929	131.951	197	3.142	2.639
111.048	133.294	198	3.174	2.666
112.173	134.643	199	3.206	2.693
113.303	136.000	200	3.238	2.720
114.439	137.363	201	3.271	2.747
115.580	138.734	202	3.303	2.775
116.727	140.111	203	3.336	2.802
117.880	141.494	204	3.369	2.830
119.039	142.885	205	3.402	2.858
120.203	144.282	206	3.447	2.896
121.373	145.686	207	3.469	2.914
122.548	147.098	208	3.502	2.942
123.729	148.515	209	3.536	2.970
124.916	149.940	210	3.569	2.999
126.109	151.370	211	3.604	3.027
127.307	152.810	212	3.638	3.056
128.511	154.255	213	3.673	3.085
129.720	155.706	214	3.707	3.114
130.936	157.165	215	3.742	3.143

VERTICAL TANKS

Gallons per Inch		Diameter in Inches	Barrels per Inch	
Imperial	U. S.		42 U. S. gal.	50 U. S. gal.
132.156	158.630	216	3.777	3.173
133.383	160.103	217	3.812	3.202
134.615	161.582	218	3.847	3.232
135.853	163.067	219	3.882	3.261
137.096	164.560	220	3.918	3.291
138.346	166.059	221	3.954	3.321
139.600	167.566	222	3.990	3.351
140.861	169.079	223	4.026	3.381
142.127	170.598	224	4.062	3.412
143.399	172.125	225	4.098	3.442
144.676	173.658	226	4.135	3.473
145.959	175.199	227	4.172	3.504
147.248	176.746	228	4.209	3.535
148.543	178.299	229	4.246	3.566
149.843	179.860	230	4.283	3.597
151.149	181.427	231	4.320	3.628
152.460	183.002	232	4.357	3.660
153.777	184.583	233	4.395	3.692
155.100	186.170	234	4.433	3.723
156.429	187.765	235	4.471	3.755
157.763	189.366	236	4.509	3.787
159.103	190.975	237	4.547	3.819
160.448	192.590	238	4.586	3.852
161.799	194.211	239	4.624	3.884
163.156	195.840	240	4.663	3.917
164.518	197.475	241	4.702	3.949
165.887	199.118	242	4.741	3.982
167.260	200.767	243	4.781	4.015
168.640	202.422	244	4.820	4.048
170.025	204.085	245	4.859	4.082
171.416	205.754	246	4.899	4.115
172.812	207.431	247	4.939	4.149
174.214	209.114	248	4.979	4.182
175.622	210.803	249	5.020	4.216
177.036	212.500	250	5.060	4.250
178.455	214.203	251	5.100	4.284
179.879	215.914	252	5.141	4.318
181.310	217.631	253	5.182	4.353
182.746	219.354	254	5.223	4.387
184.188	221.085	255	5.264	4.422
185.635	222.822	256	5.306	4.456
187.088	224.567	257	5.347	4.491
188.547	226.318	258	5.389	4.526
190.012	228.075	259	5.431	4.561
191.482	229.840	260	5.473	4.597

VERTICAL TANKS

Gallons per Inch		Diameter in Inches	Barrels per Inch	
Imperial	U. S.		42 U. S. gal.	50 U. S. gal.
192.958	231.611	261	5.515	4.632
194.439	233.390	262	5.557	4.668
195.926	235.175	263	5.600	4.703
197.419	236.966	264	5.643	4.739
198.917	238.765	265	5.686	4.775
200.421	240.570	266	5.729	4.811
201.931	242.383	267	5.772	4.848
203.447	244.202	268	5.815	4.884
204.968	246.027	269	5.858	4.920
206.494	247.860	270	5.902	4.957
208.027	249.699	271	5.946	4.994
209.565	251.546	272	5.990	5.031
211.108	253.399	273	6.034	5.068
212.658	255.258	274	6.078	5.105
214.213	257.125	275	6.123	5.142
215.774	258.998	276	6.168	5.180
217.340	260.879	277	6.212	5.217
218.912	262.766	278	6.257	5.255
220.490	264.659	279	6.302	5.293
222.073	266.560	280	6.348	5.331
223.663	268.467	281	6.392	5.369
225.257	270.382	282	6.438	5.408
226.858	272.303	283	6.484	5.446
228.464	274.230	284	6.530	5.485
230.075	276.165	285	6.576	5.523
231.693	278.106	286	6.622	5.562
233.316	280.055	287	6.669	5.601
234.945	282.010	288	6.715	5.640
236.579	283.971	289	6.762	5.679
238.219	285.940	290	6.809	5.719
239.865	287.915	291	6.856	5.758
241.516	289.898	292	6.903	5.798
243.173	291.887	293	6.951	5.838
244.836	293.882	294	6.999	5.878
246.504	295.885	295	7.046	5.918
248.178	297.894	296	7.094	5.958
249.858	299.911	297	7.141	5.998
251.544	301.934	298	7.190	6.039
352.235	303.963	299	7.238	6.079
254.931	306.000	300	7.286	6.120
256.634	308.043	301	7.335	6.161
258.342	310.094	302	7.384	6.202
260.055	312.151	303	7.433	6.243
261.775	314.214	304	7.482	6.284
263.500	316.285	305	7.532	6.326

VERTICAL TANKS

Gallons per Inch		Diameter in Inches	Barrels per Inch	
Imperial	U. S.		42 U. S. gal.	50 U. S. gal.
265.231	318.362	306	7.581	6.367
266.967	320.447	307	7.630	6.409
268.709	322.538	308	7.680	6.451
270.457	324.635	309	7.730	6.493
272.210	326.740	310	7.780	6.535
273.969	328.851	311	7.830	6.577
275.734	330.970	312	7.881	6.619
277.504	333.095	313	7.932	6.662
279.280	335.226	314	7.982	6.704
281.062	337.365	315	8.032	6.747
282.849	339.510	316	8.083	6.790
284.642	341.663	317	8.135	6.833
286.441	343.822	318	8.187	6.876
288.245	345.987	319	8.239	6.920
290.055	348.160	320	8.290	6.963
291.871	350.339	321	8.342	7.007
293.692	352.526	322	8.393	7.050
295.519	354.719	323	8.446	7.094
297.352	356.918	324	8.498	7.138
299.190	359.125	325	8.550	7.182
301.034	361.338	326	8.604	7.227
302.884	363.559	327	8.657	7.271
304.739	365.786	328	8.710	7.316
306.600	368.019	329	8.763	7.360
308.467	370.260	330	8.816	7.405
310.339	372.507	331	8.870	7.450
312.217	374.762	332	8.924	7.495
314.101	377.023	333	8.977	7.540
315.990	379.290	334	9.032	7.586
317.885	381.565	335	9.086	7.631
319.786	383.846	336	9.140	7.677
321.692	386.135	337	9.195	7.723
323.604	388.430	338	9.248	7.768
325.522	390.731	339	9.304	7.815
327.445	393.040	340	9.360	7.861
329.374	395.355	341	9.414	7.907
331.309	397.678	342	9.469	7.953
333.249	400.007	343	9.525	8.000
335.195	402.342	344	9.580	8.047
337.147	404.687	345	9.636	8.094
339.104	407.036	346	9.693	8.141
341.067	409.393	347	9.748	8.188
343.036	411.756	348	9.805	8.235
345.010	414.125	349	9.861	8.282
346.990	416.500	350	9.918	8.330

VERTICAL TANKS

Gallons per Inch		Diameter in Inches	Barrels per In	
Imperial	U. S.		42 U.S. gal.	50 U.S
348.975	418.883	351	9.975	8.3
350.967	421.274	352	10.032	8.4
352.964	423.671	353	10.088	8.4
354.966	426.074	354	10.146	8.5
356.975	428.485	355	10.203	8.5
358.989	430.902	356	10.260	8.6
361.008	433.327	357	10.317	8.6
363.034	435.758	358	10.376	8.7
365.064	438.195	359	10.434	8.7
367.101	440.640	360	10.491	8.8

HORIZONTAL TANKS

The following tables give capacities in U. S. gal. of tanks from 36 to 120 inches in diameter and one inch in length.

To obtain capacity at a given inch, multiply figures in tables by length of tank in inches.

EXAMPLE—Tank 200 inches long, 36 inches in diameter; what is capacity at 15 inches?

Under column "36 inches in diameter" and opposite 15 inches read 1.739. 1.739×200=347.800 U. S. gal. at 15 inches.

The upper half of a horizontal tank being the same as the lower half, the tables are figured for one half diameter of tank. The following shows a simple method of making tables.

Horizontal Tank 36 Inches in Diameter and 100 Inches Long

Inch	Capacity to Nearest Gallon	Difference	Capacity of Upper Half	Inch
18	220	15	235	19
17	205	16	251	20
16	189	15	266	21
15	174	15	281	22
14	159	16	297	23
13	143	14	311	24
12	129	15	326	25
11	114	14	340	26
10	100	14	354	27
9	86	13	367	28
8	73	13	380	29
7	60	12	392	30
6	48	11	403	31
5	37	10	413	32
4	27	9	422	33
3	18	8	430	34
2	10	7	437	35
1	3	3	440	36

Horizontal tank 37 Inches in Diameter and 100 Inches Long

Inch	Capacity to Nearest Gallon	Difference	Capacity of Upper Half	Inch
18.5	233	8	241	19
18	225	16	257	20
17	209	16	273	21
16	193	16	289	22
15	177	16	305	23
14	161	15	320	24
13	146	15	335	25
12	131	15	350	26
11	116	14	364	27
10	102	14	378	28
9	88	14	392	29
8	74	13	405	30
7	61	12	417	31
6	49	11	428	32
5	38	11	439	33
4	27	9	448	34
3	18	8	456	35
2	10	6	462	36
1	4	4	466	37

The capacity opposite 18.5 being omitted when putting table on regular gauge blank, a difference of 16 (twice the difference 8) being shown as the difference between 18 and 19.

When the internal diameter is not even inches, it will be found near enough for practical purposes to make a table to the nearest inch as follows:

Tank 36.25 inches diameter and 100 inches long.

Total capacity of tank=446.8 U. S. gal. Divide this by capacity of tank 36 inches diameter and one inch long (4.406 U. S. gal.) Use result (101.407) as length of tank in making tables. This divides the actual capacity into 36 inches instead of 36.25 inches, and will be found accurate enough for most purposes.

When necessary to make table in Imp. gal., multiply length by 0.83311 and use result as length in making table.

When tanks have curved ends (similar to those on tank cars) add to length of shell = of each bilge for length of tank.

If tank is more than half full and it is desired to ascertain amount of oil in tank, proceed as follows:

Example—Length=300 inches.
Diameter=60 inches.
Height of oil=45 inches.
Capacity of tank if full....... 3672 U. S. gal.
60—45=15 in. space; capacity

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

36 In. Dia.	37 In. Dia.	38 In. Dia.	Inch	39 In. Dia.	40 In. Dia.	41 In. Dia.
			20.5			2.858
			20		2.720	2.769
			19.5	2.586		
		2.445	19	2.501	2.547	2.591
	2.327		18.5			
2.203	2.247	2.290	18	2.332	2.374	2.415
2.047	2.087	2.126	17	2.165	2.202	2.239
1.893	1.928	1.963	16	1.998	2.032	2.065
1.739	1.770	1.801	15	1.832	1.863	1.894
1.585	1.613	1.643	14	1.669	1.697	1.724
1.434	1.459	1.484	13	1.509	1.533	1.557
1.286	1.308	1.330	12	1.351	1.372	1.393
1.140	1.159	1.179	11	1.198	1.216	1.233
.999	1.015	1.032	10	1.047	1.063	1.079
.861	.875	.889	9	.903	.916	.929
.729	.740	.752	8	.763	.774	.785
.603	.612	.621	7	.631	.639	.648
.483	.490	.497	6	.505	.512	.518
.371	.376	.382	5	.387	.392	.398
.268	.271	.275	4	.280	.283	.287
.175	.178	.180	3	.183	.185	.188
.096	.098	.099	2	.100	.102	.103
.034	.035	.035	1	.036	.036	.037

42 In. Dia.	43 In. Dia.	44 In. Dia.	Inch	45 In. Dia.	46 In. Dia.	47 In. Dia.
			23.5			3.755
			23		3.597	3.653
			22.5	3.442		
		3.291	22	3.344	3.397	3.450
	3.143		21.5			
2.998	3.050	3.100	21	3.149	3.199	3.248
2.817	2.864	2.908	20	2.955	3.002	3.047
2.636	2.679	2.721	19	2.763	2.805	2.846
2.455	2.495	2.533	18	2.572	2.609	2.647
2.276	2.313	2.347	17	2.381	2.416	2.450
2.098	2.132	2.163	16	2.193	2.225	2.256
1.922	1.952	1.981	15	2.009	2.037	2.064
1.750	1.776	1.802	14	1.827	1.852	1.876
1.580	1.603	1.626	13	1.648	1.672	1.693
1.414	1.434	1.454	12	1.473	1.494	1.513
1.252	1.269	1.287	11	1.304	1.321	1.338
1.094	1.110	1.125	10	1.139	1.154	1.168
.942	.955	.968	9	.980	.993	1.005
.797	.807	.817	8	.827	.838	.848
.657	.666	.675	7	.682	.691	.699
.526	.532	.540	6	.546	.552	.558
.403	.408	.414	5	.418	.424	.428
.291	.294	.297	4	.301	.304	.308
.190	.193	.194	3	.197	.199	.200
.104	.106	.107	2	.108	.110	.111
.037	.038	.038	1	.038	.039	.039

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

48 In. Dia.	49 In. Dia.	50 In. Dia.	Inch	51 In. Dia.	52 In. Dia.	53 In. Dia.
			26.5			4.776
			26		4.597	4.660
			25.5	4.422		
		4.250	25	4.309	4.371	4.431
	4.082		24.5			
3.917	3.975	4.033	24	4.085	4.146	4.203
3.707	3.765	3.817	23	3.865	3.922	3.976
3.498	3.555	3.602	22	3.647	3.700	3.749
3.289	3.345	3.388	21	3.431	3.479	3.523
3.084	3.136	3.175	20	3.216	3.259	3.300
2.881	2.928	2.964	19	3.002	3.044	3.078
2.679	2.722	2.755	18	2.790	2.825	2.859
2.478	2.517	2.548	17	2.580	2.613	2.644
2.281	2.316	2.344	16	2.374	2.405	2.432
2.087	2.118	2.145	15	2.170	2.199	2.222
1.900	1.924	1.948	14	1.971	1.996	2.016
1.716	1.734	1.756	13	1.777	1.797	1.815
1.533	1.550	1.569	12	1.585	1.605	1.622
1.353	1.370	1.386	11	1.402	1.417	1.433
1.180	1.195	1.210	10	1.223	1.235	1.251
1.017	1.027	1.040	9	1.052	1.063	1.077
.859	.866	.878	8	.888	.897	.907
.708	.716	.723	7	.729	.737	.746
.565	.575	.578	6	.583	.587	.595
.432	.440	.442	5	.447	.451	.454
.310	.317	.319	4	.319	.326	.329
.201	.205	.208	3	.211	.214	.214
.113	.114	.114	2	.114	.117	.119
.040	.041	.041	1	.041	.041	.042

54 In. Dia.	55 In. Dia.	56 In. Dia.	Inch	57 In. Dia.	58 In. Dia.	59 In. Dia.
			29.5			5.918
			29		5.719	5.790
			28.5	5.523		
		5.331	28	5.399	5.467	5.535
	5.143		27.5			
4.957	5.023	5.089	27	5.153	5.217	5.280
4.723	4.785	4.847	26	4.907	4.967	5.026
4.490	4.547	4.605	25	4.662	4.717	4.773
4.258	4.311	4.365	24	4.417	4.469	4.521
4.026	4.076	4.125	23	4.175	4.223	4.271
3.794	3.842	3.886	22	3.934	3.978	4.023
3.566	3.611	3.651	21	3.694	3.736	3.777
3.340	3.381	3.418	20	3.456	3.495	3.534
3.116	3.152	3.188	19	3.222	3.256	3.293
2.893	2.926	2.959	18	2.992	3.020	3.057
2.674	2.704	2.734	17	2.766	2.788	2.823
2.459	2.486	2.513	16	2.543	2.563	2.594
2.248	2.271	2.296	15	2.321	2.344	2.369

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

54 In. Dia.	55 In. Dia.	56 In. Dia.	Inch	57 In. Dia.	58 In. Dia.	59 In. Dia.
1.640	1.657	1.675	12	1.692	1.710	1.726
1.449	1.464	1.478	11	1.495	1.509	1.524
1.265	1.279	1.290	10	1.304	1.316	1.329
1.086	1.099	1.108	9	1.120	1.130	1.141
.915	.926	.936	8	.943	.953	.961
.755	.759	.769	7	.776	.784	.791
.602	.607	.614	6	.620	.626	.631
.461	.466	.470	5	.473	.479	.483
.331	.335	.337	4	.340	.344	.347
.217	.219	.220	3	.223	.225	.227
.119	.120	.121	2	.122	.123	.124
.042	.042	.043	1	.043	.044	.044

60 In. Dia.	61 In. Dia.	62 In. Dia.	Inch	63 In .Dia.	64 In. Dia.	65 In. Dia.
			32.5			7.182
			32		6.963	7.039
			31.5	6.747		
		6.535	31	6.610	6.686	6.755
	6.326		30.5			
6.119	6.193	6.267	30	6.337	6.410	6.472
5.858	5.929	5.999	29	6.065	6.134	6.193
5.598	5.668	5.732	28	5.794	5.858	5.915
5.339	5.407	5.465	27	5.523	5.584	5.639
5.082	5.146	5.199	26	5.254	5.310	5.363
4.826	4.885	4.935	25	4.986	5.038	5.089
4.572	4.625	4.672	24	4.722	4.769	4.817
4.318	4.366	4.412	23	4.458	4.503	4.547
4.066	4.111	4.153	22	4.196	4.239	4.281
3.818	3.859	3.898	21	3.937	3.976	4.016
3.572	3.609	3.645	20	3.683	3.718	3.756
3.328	3.363	3.397	19	3.430	3.464	3.496
3.088	3.120	3.151	18	3.181	3.213	3.242
2.852	2.881	2.910	17	2.937	2.964	2.992
2.621	2.646	2.672	16	2.698	2.723	2.748
2.392	2.417	2.440	15	2.463	2.486	2.508
2.171	2.192	2.213	14	2.232	2.254	2.274
1.954	1.972	1.991	13	2.008	2.027	2.045
1.743	1.759	1.776	12	1.791	1.808	1.823
1.538	1.552	1.567	11	1.581	1.595	1.608
1.341	1.352	1.366	10	1.378	1.390	1.401
1.152	1.161	1.173	9	1.183	1.192	1.203
.971	.980	.988	8	.996	1.005	1.013
.799	.806	.812	7	.819	.827	.833
.634	.642	.648	6	.653	.659	.664
.487	.491	.496	5	.500	.504	.508
.349	.354	.357	4	.359	.362	.365
.229	.230	.233	3	.235	.238	.238
.125	.126	.128	2	.128	.129	.131
.045	.045	.045	1	.046	.046	.047

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

66 Inches in Diam.	67 Inches in Diam.	68 Inches in Diam.	Inch	69 Inches in Diam.	70 Inches in Diam.	71 Inches in Diam.
			35.5			8.570
			35		8.330	8.413
			34.5	8.094		
		7.861	34	7.944	8.026	8.107
	7.631		33.5			
7.406	7.485	7.567	33	7.646	7.723	7.801
7.120	7.194	7.273	32	7.348	7.421	7.495
6.834	6.904	6.979	31	7.051	7.120	7.190
6.549	6.617	6.687	30	6.755	6.819	6.886
6.264	6.327	6.395	29	6.459	6.519	6.583
5.981	6.041	6.104	28	6.164	6.222	6.283
5.699	5.756	5.814	27	5.870	5.927	5.983
5.419	5.473	5.528	26	5.580	5.634	5.686
5.141	5.191	5.244	25	5.292	5.343	5.391
4.865	4.913	4.961	24	5.006	5.052	5.098
4.592	4.637	4.681	23	4.724	4.764	4.809
4.322	4.363	4.403	22	4.444	4.481	4.524
4.504	4.092	4.129	21	4.167	4.204	4.241
3.789	3.824	3.859	20	3.893	3.929	3.962
3.529	3.561	3.593	19	3.625	3.657	3.688
3.273	3.302	3.331	18	3.360	3.388	3.418
3.020	3.046	3.074	17	3.101	3.125	3.152
2.772	2.797	2.821	16	2.846	2.868	2.894
2.530	2.553	2.575	15	2.595	2.617	2.640
2.294	2.314	2.333	14	2.352	2.372	2.391
2.064	2.080	2.099	13	2.116	2.135	2.150
1.839	1.855	1.871	12	1.886	1.901	1.916
1.622	1.636	1.650	11	1.663	1.674	1.693
1.413	1.426	1.439	10	1.449	1.459	1.476
1.213	1.223	1.235	9	1.242	1.254	1.264
1.022	1.030	1.041	8	1.047	1.060	1.063
.841	.847	.855	7	.859	.871	.874
.670	.675	.680	6	.687	.689	.697
.512	.516	.520	5	.524	.528	.531
.368	.371	.374	4	.377	.378	.382
.240	.243	.244	3	.246	.249	.250
.131	.132	.133	2	.134	.135	.136
.047	.047	.047	1	.048	.048	.048

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

72 Inches in Diam.	73 Inches in Diam.	74 Inches in Diam.	Inch.	75 Inches in Diam.	76 Inches in Diam.	77 Inches in Diam.
			38.5			10.079
			38		9.819	9.912
			37.5	9.562		
		9.309	37	9.400	9.489	9.579
	9.059		36.5			
8.813	8.899	8.989	36	9.076	9.160	9.246
8.500	8.582	8.669	35	8.752	8.832	8.914
8.188	8.267	8.349	34	8.428	8.505	8.583
7.877	7.953	8.030	33	8.104	8.178	8.253
7.567	7.639	7.712	32	7.782	7.852	7.924
7.259	7.326	7.395	31	7.461	7.528	7.596
6.952	7.015	7.080	30	7.142	7.205	7.268
6.645	6.706	6.766	29	6.824	6.886	6.944
6.341	6.397	6.454	28	6.509	6.567	6.622
6.038	6.091	6.145	27	6.195	6.250	6.302
5.736	5.786	5.839	26	5.885	5.938	5.988
5.439	5.485	5.535	25	5.578	5.628	5.675
5.144	5.188	5.232	24	5.274	5.300	5.364
4.852	4.892	4.934	23	4.975	5.014	5.056
4.563	4.599	4.639	22	4.677	4.715	4.753
4.278	4.311	4.374	21	4.383	4.418	4.453
3.997	4.025	4.062	20	4.094	4.127	4.161
3.719	3.748	3.781	19	3.809	3.839	3.871
3.446	3.474	3.501	18	3.529	3.556	3.585
3.179	3.204	3.229	17	3.255	3.280	3.305
2.917	2.938	2.962	16	2.985	3.008	3.032
2.658	2.681	2.702	15	2.723	2.744	2.764
2.408	2.429	2.447	14	2.467	2.485	2.503
2.167	2.184	2.200	13	2.216	2.234	2.250
1.932	1.946	1.960	12	1.978	1.990	2.003
1.703	1.716	1.727	11	1.742	1.753	1.767
1.483	1.494	1.505	10	1.515	1.527	1.538
1.272	1.281	1.291	9	1.300	1.309	1.318
1.071	1.079	1.086	8	1.095	1.102	1.110
.880	.887	.893	7	.899	.906	.912
.701	.707	.712	6	.717	.722	.727
.536	.540	.544	5	.548	.551	.555
.386	.388	.391	4	.393	.396	.399
.252	.253	.254	3	.256	.259	.260
.138	.138	.139	2	.140	.141	.142
.048	.049	.049	1	.050	.050	.050

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

78 Inches in Diam.	79 Inches in Diam.	80 Inches in Diam.	Inch	81 Inches in Diam.	82 Inches in Diam.	83 Inches in Diam.
			41.5			11.711
			41		11.431	11.531
			40.5	11.154		
		10.880	40	10.978	11.075	11.172
	10.610		39.5			
10.343	10.439	10.533	39	10.627	10.720	10.814
10.004	10.097	10.187	38	10.277	10.365	10.456
9.666	9.756	9.841	37	9.927	10.012	10.098
9.329	9.416	9.496	36	9.578	9.659	9.741
8.994	9.076	9.151	35	9.231	9.307	9.385
8.659	8.737	8.809	34	8.884	8.957	9.031
8.325	8.398	8.468	33	8.538	8.608	8.679
7.992	8.060	8.128	32	8.194	8.260	8.328
7.660	7.724	7.789	31	7.854	7.916	7.980
7.330	7.391	7.454	30	7.514	7.575	7.633
7.001	7.059	7.120	29	7.176	7.234	7.286
6.676	6.734	6.788	28	6.842	6.893	6.947
6.354	6.407	6.458	27	6.509	6.557	6.610
6.035	6.085	6.132	26	6.181	6.228	6.274
5.719	5.764	5.809	25	5.853	5.899	5.943
5.406	5.449	5.490	24	5.532	5.574	5.615
5.096	5.138	5.175	23	5.212	5.252	5.291
4.791	4.829	4.864	22	4.900	4.933	4.970
4.487	4.523	4.557	21	4.592	4.624	4.657
4.189	4.224	4.254	20	4.286	4.316	4.346
3.897	3.928	3.956	19	3.987	4.013	4.043
3.610	3.637	3.665	18	3.691	3.717	3.742
3.329	3.355	3.377	17	3.403	3.426	3.450
3.053	3.076	3.098	16	3.120	3.141	3.164
2.784	2.804	2.825	15	2.846	2.863	2.883
2.522	2.540	2.558	14	2.576	2.592	2.612
2.267	2.282	2.299	13	2.315	2.329	2.345
2.019	2.033	2.047	12	2.062	2.074	2.089
1.779	1.791	1.804	11	1.816	1.827	1.840
1.548	1.560	1.570	10	1.582	1.591	1.606
1.328	1.336	1.345	9	1.355	1.365	1.372
1.118	1.126	1.132	8	1.141	1.148	1.156
.919	.924	.931	7	.937	.943	.950
.731	.736	.742	6	.746	.752	.757
.559	.563	.565	5	.569	.574	.576
.401	.404	.407	4	.409	.412	.415
.261	.264	.265	3	.267	.269	.269
.143	.143	.145	2	.146	.147	.148
.051	.051	.051	1	.052	.052	.053

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

84 Inches in Diam.	85 Inches in Diam.	86 Inches in Diam.	Inch	87 Inches in Diam.	88 Inches in Diam.	89 Inches in Diam.
			44.5			3.466
			44		13.165	13.273
			43.5	12.867		
		12.573	43	12.679	12.783	12.887
	12.283		42.5			
11.995	12.099	12.201	42	12.303	12.401	12.501
11.632	11.731	11.829	41	11.927	12.019	12.116
11.269	11.363	11.457	40	11.552	11.638	11.734
10.906	10.997	11.086	39	11.177	11.261	11.352
10.544	10.632	10.716	38	10.802	10.884	10.970
10.183	10.267	10.347	37	10.430	10.508	10.589
9.822	9.903	9.979	36	10.058	10.132	10.209
9.462	9.540	9.611	35	9.687	9.759	9.832
9.104	9.177	9.245	34	9.318	9.387	9.458
8.747	8.816	8.883	33	8.951	9.018	9.085
8.392	8.459	8.523	32	8.587	8.651	8.713
8.040	8.105	8.164	31	8.226	8.287	8.345
7.690	7.751	7.807	30	7.865	7.925	7.978
7.344	7.401	7.454	29	7.509	7.566	7.617
7.000	7.054	7.104	28	7.156	7.210	7.258
6.658	6.710	6.756	27	6.805	6.856	6.901
6.320	6.369	6.413	26	6.458	6.504	6.549
5.986	6.030	6.074	25	6.118	6.158	6.201
5.656	5.699	5.738	24	5.773	5.816	5.858
5.330	5.368	5.404	23	5.445	5.482	5.516
5.007	5.043	5.078	22	5.114	5.150	5.182
4.690	4.724	4.756	21	4.790	4.821	4.855
4.378	4.410	4.440	20	4.469	4.499	4.528
4.071	4.098	4.126	19	4.155	4.181	4.211
3.770	3.796	3.821	18	3.847	3.872	3.896
3.475	3.497	3.522	17	3.544	3.576	3.590
3.186	3.206	3.227	16	3.249	3.269	3.291
2.904	2.924	2.941	15	2.961	2.980	2.999
2.629	2.646	2.663	14	2.679	2.699	2.714
2.362	2.378	2.393	13	2.406	2.421	2.439
2.104	2.116	2.129	12	2.142	2.154	2.169
1.853	1.865	1.876	11	1.888	1.900	1.912
1.613	1.621	1.633	10	1.641	1.656	1.663
1.383	1.391	1.400	9	1.407	1.416	1.425
1.162	1.169	1.176	8	1.185	1.190	1.200
.954	.962	.967	7	.973	.979	.983
.760	.765	.770	6	.776	.778	.784
.580	.585	.587	5	.592	.595	.598
.417	.420	.422	4	.429	.429	.430
.272	.274	.275	3	.278	.279	.280
.148	.149	.151	2	.151	.153	.154
.053	.053	.053	1	.054	.055	.055

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

90 In. Dia.	91 In. Dia.	92 In. Dia.	Inch	93 In. Dia.	94 In. Dia.	95 In. Dia.
			47.5			15.342
			47		15.021	15.136
			46.5	14.703		
		14.388	46	14.501	14.612	14.726
	14.078		45.5			
13.770	13.880	13.988	45	14.098	14.207	14.316
13.378	13.487	13.590	44	13.696	13.802	13.905
12.987	13.094	13.194	43	13.296	13.397	13.495
12.597	12.701	12.798	42	12.896	12.993	13.086
12.209	12.308	12.403	41	12.497	12.590	12.679
11.822	11.915	12.008	40	12.098	12.187	12.273
11.436	11.525	11.613	39	11.699	11.785	11.867
11.051	11.137	11.218	38	11.301	11.384	11.463
10.667	10.750	10.826	37	10.906	10.983	11.061
10.284	10.363	10.438	36	10.513	10.587	10.662
9.903	9.977	10.050	35	10.123	10.193	10.265
9.524	9.596	9.665	34	9.733	9.800	9.870
9.184	9.216	9.281	33	9.344	9.410	9.476
8.773	8.837	8.900	32	8.962	9.024	9.084
8.403	8.463	8.523	31	8.580	8.639	8.697
8.035	8.093	8.149	30	8.200	8.257	8.313
7.670	7.724	7.777	29	7.827	7.880	7.932
7.308	7.358	7.409	28	7.456	7.506	7.553
6.948	6.996	7.046	27	7.089	7.138	7.182
6.593	6.638	6.687	26	6.727	6.771	6.812
6.242	6.283	6.331	25	6.367	6.407	6.450
5.894	5.934	5.976	24	6.013	6.052	6.090
5.552	5.588	5.626	23	5.662	5.700	5.734
5.215	5.248	5.284	22	5.320	5.352	5.386
4.883	4.916	4.948	21	4.979	5.010	5.042
4.656	4.587	4.617	20	4.647	4.673	4.701
4.235	4.264	4.292	19	4.317	4.343	4.368
3.921	3.946	3.972	18	3.996	4.021	4.045
3.611	3.635	3.657	17	3.681	3.703	3.727
3.309	3.331	3.353	16	3.375	3.393	3.414
3.014	3.035	3.056	15	3.073	3.091	3.109
2.729	2.747	2.763	14	2.781	2.796	2.814
2.452	2.468	2.480	13	2.497	2.510	2.524
2.183	2.196	2.210	12	2.222	2.232	2.248
1.922	1.934	1.946	11	1.957	1.966	1.981
1.673	1.682	1.696	10	1.703	1.714	1.723
1.433	1.443	1.455	9	1.459	1.469	1.474
1.204	1.214	1.216	8	1.226	1.232	1.240
.989	.995	1.000	7	1.007	1.010	1.019
.787	.793	.799	6	.803	.807	.812
.601	.605	.608	5	.613	.616	.618
.432	.435	.440	4	.440	.445	.445
.281	.284	.290	3	.290	.291	.292
.154	.155	.156	2	.157	.158	.160

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	96 Inches in Diameter		Inch	97 Inches in Diameter		Inches
2	.160		48.5	15.995	.160	2
1	.056	15.668	48	15.785	.057	1
		15.248	47	15.365		
		14.828	46	14.945		
		14.410	45	14.525		
		13.992	44	14.108		
		13.574	43	13.692		
		13.158	42	13.276		
		12.744	41	12.860		
		12.336	40	12.446		
		11.930	39	12.033		
		11.524	38	11.622		
		11.119	37	11.214		
		10.716	36	10.807		
		10.315	35	10.400		
		9.915	34	9.997		
		9.518	33	9.599		
		9.124	32	9.204		
		8.736	31	8.810		
		8.352	30	8.420		
		7.974	29	8.035		
		7.600	28	7.654		
		7.230	27	7.274		
		6.862	26	6.897		
		6.494	25	6.526		
		6.128	24	6.163		
		5.770	23	5.803		
		5.416	22	5.450		
		5.066	21	5.101		
		4.726	20	4.757		
		4.394	19	4.421		
		4.068	18	4.092		
		3.752	17	3.770		
		3.444	16	3.455		
		3.139	15	3.145		
		2.838	14	2.844		
		2.546	13	2.554		
		2.260	12	2.273		
		1.990	11	2.001		
		1.728	10	1.742		
		1.480	9	1.492		
		1.240	8	1.254		
		1.016	7	1.032		
		.804	6	.821		
		.620	5	.625		
		.447	4	.448		
		.292	3	.293		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	98 Inches in Diameter		Inch	99 Inches in Diameter		Inches
3	.295		49:5	16.662	.297	3
2	.162	16.327	49	16.446	.162	2
1	.058	15.898	48	16.016	.058	1
		15.473	47	15.587		
		15.049	46	15.159		
		14.626	45	14.732		
		14.205	44	14.305		
		13.784	43	13.880		
		13.363	42	13.458		
		12.944	41	13.036		
		12.527	40	12.615		
		12.111	39	12.197		
		11.698	38	11.780		
		11.287	37	11.365		
		10.877	36	10.952		
		10.468	35	10.539		
		10.063	34	10.128		
		9.661	33	9.723		
		9.263	32	9.322		
		8.867	31	8.921		
		8.473	30	8.526		
		8.085	29	8.136		
		7.700	28	7.747		
		7.318	27	7.362		
		6.940	26	6.982		
		6.569	25	6.607		
		6.203	24	6.239		
		5.841	23	5.874		
		5.484	22	5.514		
		5.131	21	5.160		
		4.786	20	4.814		
		4.449	19	4.472		
		4.116	18	4.138		
		3.792	17	3.811		
		3.472	16	3.491		
		3.160	15	3.181		
		2.856	14	2.878		
		2.565	13	2.583		
		2.282	12	2.298		
		2.016	11	2.025		
		1.754	10	1.759		
		1.501	9	1.508		
		1.260	8	1.266		
		1.035	7	1.040		
		.823	6	.828		
		.628	5	.633		
		.453	4	.453		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	100 Inches in Diameter		Inch	101 Inches in Diameter		Inches
4	.456		50.5	17.342	.458	4
3	.297	17.000	50	17.122	.298	3
2	.162	16.565	49	16.683	.162	2
1	.058	16.132	48	16.247	.058	1
		15.699	47	15.812		
		15.267	46	15.377		
		14.837	45	14.942		
		14.407	44	14.507		
		13.978	43	14.073		
		13.551	42	13.642		
		13.125	41	13.213		
		12.700	40	12.784		
		12.277	39	12.356		
		11.855	38	11.931		
		11.436	37	11.508		
		11.020	36	11.090		
		10.605	35	10.672		
		10.194	34	10.257		
		9.785	33	9.846		
		9.379	32	9.437		
		8.977	31	9.032		
		8.578	30	8.630		
		8.184	29	8.233		
		7.793	28	7.840		
		7.407	27	7.450		
		7.024	26	7.065		
		6.647	25	6.685		
		6.274	24	6.311		
		5.908	23	5.942		
		5.546	22	5.579		
		5.190	21	5.221		
		4.841	20	4.868		
		4.498	19	4.523		
		4.162	18	4.185		
		3.833	17	3.855		
		3.511	16	3.531		
		3.198	15	3.215		
		2.893	14	2.908		
		2.597	13	2.612		
		2.311	12	2.324		
		2.035	11	2.041		
		1.769	10	1.779		
		1.516	9	1.524		
		1.274	8	1.282		
		1.046	7	1.053		
		.833	6	.838		
		.636	5	.640		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	102 Inches in Diameter		Inch	103 Inches in Diameter		Inches
5	.642		51.5	18.035	.646	5
4	.458	17.687	51	17.811	.462	4
3	.300	17.246	50	17.364	.301	3
2	.163	16.805	49	16.918	.164	2
1	.058	16.364	48	16.473	.059	1
		15.924	47	16.030		
		15.485	46	15.587		
		15.047	45	15.144		
		14.609	44	14.701		
		14.172	43	14.259		
		13.738	42	13.819		
		13.304	41	13.384		
		12.871	40	12.950		
		12.440	39	12.516		
		12.011	38	12.083		
		11.587	37	11.655		
		11.163	36	11.229		
		10.743	35	10.805		
		10.325	34	10.386		
		9.911	33	9.968		
		9.498	32	9.556		
		9.087	31	9.147		
		8.680	30	8.738		
		8.282	29	8.331		
		7.884	28	7.930		
		7.497	27	7.537		
		7.108	26	7.148		
		6.722	25	6.764		
		6.340	24	6.387		
		5.972	23	6.010		
		5.608	22	5.644		
		5.251	21	5.281		
		4.895	20	4.924		
		4.549	19	4.576		
		4.208	18	4.230		
		3.877	17	3.896		
		3.554	16	3.568		
		3.235	15	3.250		
		2.916	14	2.938		
		2.622	13	2.639		
		2.333	12	2.348		
		2.056	11	2.069		
		1.787	10	1.798		
		1.531	9	1.542		
		1.278	8	1.295		
		1.057	7	1.064		
		.845	6	.844		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	104 Inches in Diameter		Inch	105 Inches in Diameter		Inches
6	.850		52.5	18.742	.853	6
5	.649	18.387	52	18.513	.652	5
4	.467	17.936	51	18.057	.469	4
3	.302	17.485	50	17.603	.304	3
2	.164	17.035	49	17.150	.165	2
1	.059	16.587	48	16.697	.059	1
		16.140	47	16.245		
		15.693	46	15.794		
		15.247	45	15.343		
		14.802	44	14.893		
		14.357	43	14.447		
		13.912	42	14.002		
		13.470	41	13.558		
		13.032	40	13.116		
		12.597	39	12.675		
		12.164	38	12.237		
		11.732	37	11.802		
		11.297	36	11.371		
		10.872	35	10.940		
		10.450	34	10.511		
		10.029	33	10.088		
		9.610	32	9.666		
		9.198	31	9.249		
		8.789	30	8.837		
		8.382	29	8.430		
		7.978	28	8.025		
		7.582	27	7.623		
		7.190	26	7.229		
		6.804	25	6.841		
		6.423	24	6.457		
		6.046	23	6.076		
		5.671	22	5.704		
		5.308	21	5.336		
		4.950	20	4.978		
		4.599	19	4.626		
		4.255	18	4.277		
		3.920	17	3.938		
		3.588	16	3.608		
		3.267	15	3.285		
		2.955	14	2.971		
		2.653	13	2.667		
		2.361	12	2.373		
		2.080	11	2.090		
		1.809	10	1.814		
		1.548	9	1.556		
		1.300	8	1.308		
		1.068	7	1.074		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	106 Inches in Diameter		Inch	107 Inches in Diameter		Inches
7	1.077		53.5	19.463	1.084	7
6	.858	19.101	53	19.230	.862	6
5	.655	18.639	52	18.766	.658	5
4	.470	18.180	51	18.303	.473	4
3	.306	17.723	50	17.841	.306	3
2	.166	17.266	49	17.381	.167	2
1	.059	16.810	48	16.922	.060	1
		16.354	47	16.463		
		15.898	46	16.004		
		15.444	45	15.545		
		14.991	44	15.087		
		14.539	43	14.629		
		14.089	42	14.176		
		13.642	41	13.724		
		13.196	40	13.275		
		12.752	39	12.828		
		12.310	38	12.384		
		11.869	37	11.943		
		11.434	36	11.503		
		11.005	35	11.069		
		10.576	34	10.635		
		10.150	33	10.205		
		9.725	32	9.779		
		9.303	31	9.354		
		8.888	30	8.937		
		8.474	29	8.523		
		8.069	28	8.116		
		7.668	27	7.710		
		7.272	26	7.312		
		6.877	25	6.919		
		6.491	24	6.526		
		6.111	23	6.143		
		5.733	22	5.767		
		5.366	21	5.395		
		5.005	20	5.029		
		4.648	19	4.673		
		4.300	18	4.323		
		3.960	17	3.980		
		3.626	16	3.643		
		3.302	15	3.320		
		2.988	14	3.001		
		2.680	13	2.696		
		2.384	12	2.398		
		2.101	11	2.110		
		1.824	10	1.834		
		1.564	9	1.571		
		1.314	8	1.320		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	108 Inches in Diameter		Inch	109 Inches in Diameter		Inches
8	1.323		54.5	20.198	1.336	8
7	1.085	19.828	54	19.962	1.095	7
6	.868	19.359	53	19.490	.871	6
5	.662	18.892	52	19.019	.665	5
4	.476	18.426	51	18.548	.477	4
3	.309	17.961	50	18.077	.309	3
2	.169	17.496	49	17.607	.170	2
1	.060	17.031	48	17.137	.060	1
		16.567	47	16.670		
		16.103	46	16.203		
		15.639	45	15.737		
		15.178	44	15.272		
		14.719	43	14.810		
		14.263	42	14.349		
		13.810	41	13.890		
		13.359	40	13.435		
		12.910	39	12.983		
		12.464	38	12.531		
		12.019	37	12.083		
		11.576	36	11.639		
		11.135	35	11.197		
		10.698	34	10.758		
		10.265	33	10.322		
		9.836	32	9.892		
		9.412	31	9.463		
		8.992	30	9.037		
		8.576	29	8.619		
		8.165	28	8.207		
		7.756	27	7.796		
		7.352	26	7.391		
		6.953	25	6.993		
		6.560	24	6.597		
		6.176	23	6.209		
		5.797	22	5.827		
		5.428	21	5.453		
		5.059	20	5.084		
		4.696	19	4.720		
		4.343	18	4.367		
		4.000	17	4.022		
		3.661	16	3.682		
		3.335	15	3.353		
		3.020	14	3.032		
		2.711	13	2.723		
		2.409	12	2.422		
		2.121	11	2.131		
		1.843	10	1.852		
		1.575	9	1.586		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	110 Inches in Diameter		Inch	111 Inches in Diameter		Inches
9	1.599		55.5	20.946	1.600	9
8	1.347	20.570	55	20.703	1.347	8
7	1.102	20.093	54	20.219	1.106	7
6	.876	19.616	53	19.738	.880	6
5	.671	19.140	52	19.259	.671	5
4	.479	18.664	51	18.781	.480	4
3	.310	18.188	50	18.305	.312	3
2	.170	17.715	49	17.829	.170	2
1	.060	17.244	48	17.353	.061	1
		16.774	47	16.877		
		16.304	46	16.403		
		15.836	45	15.932		
		15.368	44	15.461		
		14.905	43	14.992		
		14.444	42	14.523		
		13.983	41	14.064		
		13.524	40	13.589		
		13.066	39	13.130		
		12.608	38	12.676		
		12.155	37	12.223		
		11.704	36	11.772		
		11.258	35	11.323		
		10.816	34	10.879		
		10.378	33	10.437		
		9.944	32	10.002		
		9.514	31	9.570		
		9.087	30	9.141		
		8.664	29	8.714		
		8.244	28	8.290		
		7.833	27	7.878		
		7.428	26	7.468		
		7.026	25	7.063		
		6.628	24	6.665		
		6.238	23	6.274		
		5.856	22	5.888		
		5.481	21	5.509		
		5.116	20	5.136		
		4.754	19	4.771		
		4.396	18	4.413		
		4.046	17	4.059		
		3.704	16	3.718		
		3.366	15	3.385		
		3.036	14	3.062		
		2.724	13	2.748		
		2.428	12	2.445		
		2.140	11	2.153		
		1.864	10	1.870		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	112 Inches in Diameter		Inch	113 Inches in Diameter		Inches
10	1.881		56.5	21.707	1.887	10
9	1.610	21.325	56	21.461	1.615	9
8	1.350	20.837	55	20.971	1.357	8
7	1.111	20.349	54	20.481	1.113	7
6	.885	19.863	53	19.991	.886	6
5	.674	19.379	52	19.504	.675	5
4	.482	18.897	51	19.017	.486	4
3	.314	18.415	50	18.530	.317	3
2	.171	17.936	49	18.044	.171	2
1	.061	17.457	48	17.559	.062	1
		16.980	47	17.074		
		16.503	46	16.590		
		16.028	45	16.112		
		15.554	44	15.638		
		15.080	43	15.165		
		14.610	42	14.692		
		14.141	41	14.221		
		13.672	40	13.751		
		13.210	39	13.283		
		12.751	38	12.821		
		12.292	37	12.361		
		11.838	36	11.904		
		11.388	35	11.449		
		10.942	34	10.999		
		10.497	33	10.552		
		10.055	32	10.108		
		9.620	31	9.669		
		9.188	30	9.235		
		8.761	29	8.805		
		8.338	28	8.383		
		7.919	27	7.962		
		7.507	26	7.548		
		7.101	25	7.139		
		6.703	24	6.736		
		6.307	23	6.339		
		5.916	22	5.948		
		5.536	21	5.560		
		5.163	20	5.188		
		4.795	19	4.817		
		4.434	18	4.457		
		4.081	17	4.101		
		3.738	16	3.755		
		3.402	15	3.419		
		3.077	14	3.091		
		2.764	13	2.772		
		2.457	12	2.468		
		2.162	11	2.171		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	114 Inches in Diameter		Inch	115 Inches in Diameter		Inches
11	2.183		57.5	22.482	2.192	11
10	1.898	22.093	57	22.230	1.907	10
9	1.624	21.599	56	21.733	1.632	9
8	1.365	21.105	55	21.236	1.371	8
7	1.120	20.611	54	20.740	1.126	7
6	.890	20.117	53	20.244	.895	6
5	.681	19.624	52	19.748	.684	5
4	.488	19.132	51	19.252	.490	4
3	.317	18.643	50	18.756	'319	3
2	.172	18.155	49	18.262	.173	2
1	.062	17.668	48	17.772	.062	1
		17.181	47	17.282		
		16.695	46	16.795		
		16.212	45	16.309		
		15.731	44	15.823		
		15.253	43	15.341		
		14.775	42	14.862		
		14.299	41	14.383		
		13.828	40	13.906		
		13.360	39	13.431		
		12.893	38	12.964		
		12.428	37	12.497		
		11.967	36	12.033		
		11.511	35	11.572		
		11.057	34	11.116		
		10.609	33	10.664		
		10.165	32	10.217		
		9.722	31	9.771		
		9.288	30	9.331		
		8.856	29	8.898		
		8.425	28	8.468		
		8.003	27	8.040		
		7.583	26	7.622		
		7.176	25	7.213		
		6.770	24	6.806		
		6.369	23	6.401		
		5.978	22	6.007		
		5.592	21	5.619		
		5.212	20	5.238		
		4.841	19	4.865		
		4.476	18	4.499		
		4.120	17	4.139		
		3.771	16	3.786		
		3.436	15	3.451		
		3.109	14	3.121		
		2.786	13	2.799		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	116 Inches in Diameter		Inch	117 Inches in Diameter		Inches
12	2.502		58.5	23.271	2.516	12
11	2.201	22.875	58	23.016	2.215	11
10	1.914	22.371	57	22.506	1.925	10
9	1.639	21.868	56	21.998	1.645	9
8	1.376	21.366	55	21.493	1.385	8
7	1.131	20.865	54	20.989	1.136	7
6	.899	20.365	53	20.485	.903	6
5	.686	19.866	52	19.992	.689	5
4	.492	19.368	51	19.479	.496	4
3	.320	18.870	50	18.977	.321	3
2	.175	18.373	49	18.476	.175	2
1	.062	17.877	48	17.975	.063	1
		17.382	47	17.478		
		16.888	46	16.984		
		16.398	45	16.491		
		15.911	44	15.999		
		15.427	43	15.510		
		14.944	42	15.024		
		14.462	41	14.540		
		13.981	40	14.056		
		13.501	39	13.578		
		13.023	38	13.102		
		12.549	37	12.632		
		12.079	36	12.162		
		11.613	35	11.698		
		11.152	34	11.238		
		10.697	33	10.778		
		10.250	32	10.323		
		9.812	31	9.872		
		9.377	30	9.428		
		8.944	29	8.988		
		8.513	28	8.555		
		8.086	27	8.125		
		7.663	26	7.701		
		7.247	25	7.282		
		6.838	24	6.870		
		6.434	23	6.460		
		6.036	22	6.065		
		5.645	21	5.675		
		5.262	20	5.292		
		4.888	19	4.913		
		4.519	18	4.541		
		4.160	17	4.179		
		3.813	16	3.826		
		3.468	15	3.483		
		3.136	14	3.149		
		2.813	13	2.828		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	118 Inches in Diameter		Inch	119 Inches in Diameter		Inches
12	2.526		59.5	24.074	2.535	12
11	2.223	23.671	59	23.816	2.232	11
10	1.932	23.160	58	23.301	1.938	10
9	1.655	22.649	57	22.787	1.659	9
8	1.390	22.138	56	22.273	1.396	8
7	1.141	21.627	55	21.760	1.146	7
6	.909	21.117	54	21.247	.910	6
5	.694	20.609	53	20.734	.696	5
4	.497	20.102	52	20.221	.498	4
3	.322	19.597	51	19.710	.325	3
2	.175	19.092	50	19.203	.178	2
1	.063	18.587	49	18.697	.063	1
		18.083	48	18.191		
		17.582	47	17.685		
		17.082	46	17.182		
		16.584	45	16.681		
		16.088	44	16.180		
		15.595	43	15.682		
		15.105	42	15.188		
		14.620	41	14.697		
		14.137	40	14.209		
		13.654	39	13.725		
		13.174	38	13.245		
		12.698	37	12.767		
		12.225	36	12.291		
		11.758	35	11.818		
		11.292	34	11.350		
		10.832	33	10.888		
		10.377	32	10.429		
		9.924	31	9.975		
		9.476	30	9.524		
		9.031	29	9.082		
		8.595	28	8.643		
		8.165	27	8.207		
		7.739	26	7.779		
		7.319	25	7.357		
		6.905	24	6.940		
		6.496	23	6.529		
		6.094	22	6.127		
		5.702	21	5.730		
		5.317	20	5.342		
		4.937	19	4.959		
		4.562	18	4.587		
		4.197	17	4.220		
		3.845	16	3.867		
		3.501	15	3.520		
		3.163	14	3.180		
		2.841	13	2.853		

HORIZONTAL TANKS

Multiply capacity in tables by length of tank in inches.

Inches	120 Inches in Diameter		Inches
13	2.866	24.479	60
12	2.537	23.954	59
11	2.239	23.434	58
10	1.949	22.914	57
9	1.668	22.395	56
8	1.396	21.877	55
7	1.151	21.359	54
6	.915	20.842	53
5	.699	20.328	52
4	.501	19.815	51
3	.326	19.305	50
2	.178	18.795	49
1	.063	18.287	48
		17.780	47
		17.273	46
		16.767	45
		16.265	44
		15.768	43
		15.273	42
		14.779	41
		14.287	40
		13.797	39
		13.314	38
		12.833	37
		12.354	36
		11.881	35
		11.411	34
		10.944	33
		10.483	32
		10.024	31
		9.567	30
		9.124	29
		8.683	28
		8.244	27
		7.816	26
		7.393	25
		6.976	24
		6.561	23
		6.153	22
		5.751	21
		5.363	20
		4.981	19
		4.608	18
		4.240	17
		3.882	16
		3.538	15
		3.198	14

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